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WATER SUPPLY AND WATER QUALITY CONTROL STUDY: COLUMBIA BASIN IRRIGATION PROJECT, UPPER COLUMBIA RIVER BASIN, WASHINGTON. AN EVALUATION OF PRESENT AND FUTURE MUNICIPAL, INDUSTRIAL, AND DOMESTIC WATER SUPPLY AND QUALITY CONTROL NEEDS

Public Health Service, Portland, Oregon

July 1965

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WATER SUPPLY AND WATER QUALITY CONTROL STUDY

COLUMBIA BASIN IRRIGATION PROJECT
UPPER COLUMBIA RIVER BASIN, WASHINGTON

An Evaluation of Present and Future Municipal, Industrial,
and Domestic Water Supply and Quality Control Needs

Columbia Basin Irrigation Project
WASHINGTON
MONT.
OREGON
IDAHO

U. S. DEPARTMENT OF HEALTH, EDUCATION, AND WELFARE
Public Health Service
Water Supply and Pollution Control Program, Pacific Northwest
Region IX - Portland, Oregon

JULY, 1965

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Water and water quality needs for the area included in the Bureau of Reclamation's Columbia Basin Irrigation Project in south-central Washington, presently developed, authorized, and proposed, are reported. The report examines, evaluates, and projects all available data on water uses, wastes sources, and water quality in order to determine present and future needs for domestic, municipal, and industrial water supply and water quality control and to predict the effects of increased irrigation development on surface and ground water quality.

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WATER SUPPLY AND WATER QUALITY CONTROL STUDY

COLUMBIA BASIN IRRIGATION PROJECT
UPPER COLUMBIA RIVER BASIN, WASHINGTON

An investigation has been made which discloses present and future needs for domestic, municipal and industrial water supply, and water quality control, and which predicts the effects of increased irrigation development on surface and ground water quality. Future water needs and quality predictions are based on economic, demographic, and engineering studies.

Prepared at the Request of the U. S. Department of Interior
Bureau of Reclamation, Columbia Basin Project,
Ephrata, Washington

U. S. DEPARTMENT OF HEALTH, EDUCATION, AND WELFARE
Public Health Service
Water Supply and Pollution Control Program, Pacific Northwest
Region IX - Portland, Oregon

JULY, 1965

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I. INTRODUCTION

A. Request and Authority

The request for this report was made by the U. S. Bureau of Reclamation, Ephrata, Washington, by letter dated May 29, 1963. A "Memorandum of Agreement", outlining the studies and evaluations to be made, was prepared and executed on November 1, 1963. A copy of this "Memorandum of Agreement" is attached (Appendix D). Authority for the investigation and report is the Federal Water Pollution Control Act, as amended (33 U.S.C. 466 et seq.).

B. Purpose and Scope

The purpose of this investigation is to cooperate with and render assistance to a public agency in the conduct of investigations relating to causes, prevention and control of present and future water pollution, and to determine present and future municipal and industrial water supply requirements. To accomplish this, all available data on water uses, waste sources and water quality were examined, evaluated and projected. Field data collected by the Public Health Service during the summer and fall of 1964 aided the evaluations.

The areas covered in the report are those included in the Bureau of Reclamation's Columbia Basin Irrigation Project, consisting of areas presently developed, authorized and proposed.

Evaluations include projected conditions to the year 2010, with an interim period at 1985. An economic base study was prepared for this purpose, using statistics on Adams, Franklin and Grant Counties.

Forecasts of future growths were prepared for developments with and without the proposed project enlargement.

The evaluations are subject to modification pending completion of studies in this region by the Public Health Service, Columbia River Basin Comprehensive Project for Water Supply and Pollution Control. The evaluations made and conclusions drawn are suitable for project feasibility and developmental planning purposes.

C. Acknowledgments

This investigation and study was aided materially by the Bureau of Reclamation, Washington State Department of Health, Washington State Pollution Control Commission, officials and representatives of the cities in the study area, and reports of the University of Washington and Washington State University.

II. SUMMARY OF FINDINGS AND CONCLUSIONS

A. Summary of Findings

1. The Columbia River Basin Irrigation Project is located in an arid region east of the Cascade Mountains in South Central Washington. The project came into being about the year 1952 when water, in relatively substantial amounts, was first diverted to this region from the Columbia River for agricultural development.

2. The project area, or the area within which water quality and water use investigations were conducted, involves a land area of roughly 4,000 square miles, 15 per cent of which is presently irrigated and 45 per cent of which is planned for ultimate irrigation development. The step-wise plan of irrigation development consists of service to 711,000 acres of land by means of the existing East Low Canal and service to 386,000 additional acres by means of the proposed East High Canal. In 1962 about 346,000 acres were irrigated.

3. At present, about 1,900,000 acre-feet of water are diverted annually to the project area. With ultimate development, nearly 4,400,000 acre-feet of water will be diverted to the region annually. Considerable quantities of ground water have accumulated and water tables have risen significantly in many areas since the start of the project.

4. Ground water movement generally follows the surface contours of the region. Its occurrence and abundance relate directly to those areas adjacent to and over which waters are conveyed and onto which water is applied for irrigation. Surface contours are generally southerly and may be characterized by five relatively distinct drainage areas. Waters underlying these areas, in some respects, differ from one another in hydrologic and water quality characteristics.

5. The economy of the region is characterized by agricultural activities, processing of agricultural products and various agricultural services. Without exception, the economy of the area is highly dependent upon the availability of an adequate water supply of satisfactory quality.

6. The total population of the region, in 1960, was about 72,000, of which 46,000 resided in incorporated places. Present incorporated populations are located in 16 development centers throughout the region. With ultimate irrigation development, the total population of the region in the next fifty years is projected to increase to 259,000, with populations in incorporated places comprising about 85 per cent of this number. About 20 per cent of the population growth, with ultimate development, would be associated with the proposed East High Canal. Future increases in incorporated populations are expected to take place in and around population centers presently in existence.

7. Present and projected populations, as distributed by drainage areas of the region from north to south, are approximately as follows:

Area Number	1960		1985		2010	
	Urban	Rural	Urban	Rural	Urban	Rural
1	23,300	16,700	53,000	20,000	94,000	20,000
2	400	300	2,500	2,000	2,500	2,000
3	3,900	3,000	13,000	11,000	26,000	17,000
4	400	500	2,000	6,000	2,000	6,000
5	1,700	5,100	6,000	12,000	9,000	13,000
(Pasco - 16,400)						

The population of the City of Pasco, located on the Columbia River in Area Number 5, is not included in water supply studies.

8. In 1963 there were eighteen public water systems serving about 46,400 people. Seventeen of these supplies were from ground water (40 to 50 wells) and served about 35,000 people. The City of Pasco, utilizing surface water from the Columbia River (5,050 acre-feet) served about 16,000 persons during that year. Including the industries in the region which use ground water, about 15,600 acre-feet of ground water was used for municipal and industrial (M&I) supply. By the years 1985 and 2010, with ultimate project development, the total annual demand for water for M&I purposes is projected to be 30,000 and 52,000 acre-feet for these years respectively (excludes Pasco area).

9. Rural domestic water needs for 1985 and 2010 are projected to increase to about 3,200 and 3,600 acre-feet annually by these respective years. Present rural domestic water use from ground water sources is estimated to be about 1,900 acre-feet annually.

10. Sources of organic pollution in the area consist of domestic sewage and wastes produced in the processing of potatoes, sugar beets, milk, meats, and miscellaneous vegetable crops. Total waste production in the study area in terms of five-day biochemical oxygen demand (BOD_5) averages 850,000 population equivalents (PE) per day. During peak industrial operation (June through March), total raw industrial waste production is about 968,000 PE per day. With ultimate project development, raw waste production by the year 2010 is projected to increase to 6,000,000 PE per day. About one-third of the projected 2010 waste production would be attributed to developments associated with the proposed East High Canal.

11. Current waste disposal practices rely heavily on land disposal techniques. The lack of sufficiently large bodies of water or streams into which to dilute and assimilate waste precludes this means of waste effluent disposal. Major communities in the area (population 43,600) provide sewage collection and treatment facilities. A number of small rural communities and the entire rural farm population (population 33,800) treat wastes by septic tanks with subsurface effluent disposal. The City of Moses Lake discharges plant effluents to Moses Lake, and Pasco discharges treatment plant effluents

to the Columbia River. Industrial waste treatment is accomplished mainly by lagoons or primary settling with effluent disposal to land for irrigation. The methods of waste disposal have proved to be adequate. Low dissolved oxygen (2.7 mg/1) and algal blooms of nuisance significance, however, have occurred in Moses Lake during some summer months. The problem is believed associated with nutrient rich waters entering the lake as surface and sub-surface flows and as sewage effluent. Other problems are those of relatively heavy growths of algae and aquatic plants in irrigation canals.

12. The major uses of water for which water quality is important in the region are domestic, municipal and industrial water supply, irrigation, fisheries, and recreation. Water diverted from the Columbia River is of excellent quality for all of these uses. Return water within the project, though somewhat higher in mineral content, is of satisfactory quality to meet most of the needs. For example, Columbia River water contains somewhat less than 125 mg/1 of total dissolved solids. Total dissolved solids in canal and reservoir waters within the project, though higher, do not exceed 500 mg/1. Nitrate-nitrogen concentrations range generally between 0.01 and 0.06 mg/1. Pesticides in trace amounts have been found in some surface waters. Pesticides generally occur only intermittently and have been found in concentrations in the order of 150 parts per trillion (0.000150 parts per million).

13. Ground water in some areas is of undesirable quality for domestic purposes. Samples showing total dissolved solids, ranging between 500 and 1,250 mg/1, and nitrate-nitrogen contents, ranging from a fraction to upwards of 180 mg/1, have been reported. The higher values are generally found at shallower depths. Trace amounts of pesticides in the order of 1,500 parts per trillion (0.00150 parts per million) have been detected in shallow ground water layers in some areas.

14. Resident fish populations in the project areas have contributed significantly to recreation and water-based activities. Lakes that were too alkaline to support fish life prior to the project have freshened and now support considerable fish production.

B. Conclusions

1. Additional irrigation development, including that anticipated with East High Canal, is not expected to cause a significant change in the quality of lakes and streams in the region. Except for an occasional odor problem, municipal and industrial waste control by solids removal with disposal of effluents to lagoons and/or to land appears to have provided adequate protection of surface and ground water quality to date.

2. With the exception of a possibility for controlling algal growths in Moses Lake by direct routing of Columbia River water through the lake there are no present or expected future water quality problems requiring provisions for control in the design or operation of the project. Efficient use of irrigation water and agricultural chemicals on the land, however, should be practiced.

3. A surveillance program designed to examine the effectiveness of water quality control practices in the area should be initiated. The details of such a program should be developed and agreed upon by local, State and Federal agencies having interests in and responsibilities for maintenance of water quality and protection of public health.

4. The quality of ground water in Drainage Areas 1, 3, and 4 (Quincy-Ephrata; Lower Crab Creek; and Wahluke Slope drainages respectively) is not expected to change with increased irrigation and should remain suitable for domestic use. Ground water quality in Area 2 (Moses Lake-Potholes locale) may be reduced in quality with further development; and Area 5 (Mesa-Eltopia locale), which is presently marginal to unsatisfactory in quality, may or may not undergo improvement with further development.

5. A surveillance of ground water quality, particularly in Drainage Areas 2 and 5, should be initiated. A change in source or other alternative means for acquiring better water for domestic supply in these areas also should be investigated. These supplies are expected

to involve 26,500 persons and needs for 5,200 acre-feet of water per year by the end of the study period.

6. Vector problems are of significance to the area and are expected to become of greater importance with further irrigation development. It is recommended that practices for the prevention and elimination of problems associated with vectors be carried out as outlined by the Public Health Service, Communicable Disease Center, and the Washington State Department of Health in Appendix E.

III. PROJECT DESCRIPTION

A. Location

The Columbia Basin Irrigation Project is located in the arid region of South Central Washington and lies south of the great westerly curve of the Columbia River below the mouth of the Spokane River. (See Figure 1, Location Map, inside back cover.) The area is bounded on the west by the Columbia River, on the south by the Snake River, on the east and north by low hills. The area is about 125 miles long, north-to-south, and is about 70 miles wide east-to-west.

The project's water supply consists of pumping from Franklin D. Roosevelt Lake back of Grand Coulee Dam into Banks Lake, from which it flows about 10 miles into Long Lake, a regulating reservoir about 7 miles in length. Water is then distributed to the lands to be irrigated by a system of canals, laterals, pumps, and equalizing and regulating lakes and reservoirs.

About 460,000 acres, out of 711,000 acres presently authorized have been developed. About 300 miles of major canals, 1,800 miles of laterals and 1,000 miles of drains and wasteways, are presently completed. An additional 100 miles of major canals, 1,000 miles of laterals and 1,500 miles of wasteways and drains, remain to be constructed under presently authorized development.

B. Proposed Project

It is proposed by the Bureau of Reclamation to enlarge the irrigation project a total of about 1,097,000 acres by adding East High Canal, equalizing reservoirs, pumps, and 200 miles of major canals, 1,400 miles of laterals and 1,100 miles of drains and wasteways.

With completion of East Low (Development presently authorized) annual diversions will be 3,000,000 acre-feet. The enlargement will require additional diversions from the Columbia River of about 1,400,000 acre-feet, resulting in ultimate total annual diversions of about 4,400,000 acre-feet of water to the area. With this development there will be additional regulating reservoirs in the delivery system and more water in the wasteways and natural drainageways. One of the larger water bodies that will be formed is a lake, about 13 miles long, with about 2,500-acre surface area in Washtucna Coulee. Drainage from this area is to the southeast and flow is into the Snake River just below Lower Monumental Dam.

IV. STUDY AREA DESCRIPTION

A. Boundaries

The study area is the present and authorized irrigated area of the project, plus the area associated with the proposed East High Canal. The area is bounded by Long Lake on the north, Columbia River on the west, Snake River on the south, and the low hills on the east. Lands up to 1,800 feet MSL would be supplied with water under the proposed enlargement. The study area is shown on Figure 1, Location Map.

The principal communities, with populations of 1,000 or greater, are Ephrata, Quincy, Soap Lake, Moses Lake, Othello, and Pasco. The irrigation project boundary describes the water supply and water quality study area and includes portions of Adams, Franklin, Walla Walla, and Grant Counties. The economic study area consists of a group of county census units as defined in Chapter VI and closely coincides with the project area. The area is roughly 80 miles long and 70 miles wide at the widest portion. The total area is about 3,700 square miles (approximately 2,400,000 acres), of which 1,097,000 acres would be irrigated with full development.

B. Physical Features

1. Topography and Soils

The project area is tableland, sloping gently southwestward, with a diversity of topography formed by glaciation during the Pleistocene Age, as shown in Chapter V, Water Resources, Figure 3.

The elevation of irrigable lands ranges from about 400 feet in the southwest to 1,800 feet in the northeast.

There are several large areas within the project which are too rough, steep, sandy, rocky, or otherwise unsuited for irrigation. There are also scattered bodies of land which are suitable for irrigation but which are too small or are located in areas impractical to be served. A considerable portion of the Wahluke slope has been excluded from the project because of health and security reasons imposed by the Atomic Energy Commission (see Figure 1).

The project area is a part of the extensive Columbia River plateau, which was formed by the extrusion of lava during the Eocene, Miocene, and Pliocene epochs throughout a large part of Eastern Washington, Eastern Oregon, and Western Idaho. After basalt was extruded, the region was warped into the form of a broad basin in which several subbasins were formed by locally steeper folding and by faulting. The basalt bedrock and coarse-grained sedimentary deposits constitute the important sources of ground water in the area. The basalt ridges that separate the subbasins are also important in that they may act as ground water barriers, retarding the movement of ground water from one subbasin to another. The western portion of the project area is a series of north-south slopes and faulting with natural drainageways intersecting in an east-west direction, as shown in Figure 3.

The project is primarily covered with soils developed from wind-laid, unconsolidated, glacial, or sedimentary material. Clay, silt, sand and gravel accumulated during the glacial period and further amounts of silt and sand have been deposited by wind action.

In the valleys and on the hills in the north and northwest part of the project area, the soils are derived mainly from glacial outwash and unsorted glacial deposits. In the lower western part are sizeable tracts containing fertile loams, although there are also some shallow rocky soils, others of deep sand, and some of a shallow depth to hardpan.

On the higher lands of the plateau in the north and east part of the project are soils ranging from sandy loams and silt loams to loessal soils. These soils are characteristically deep, water-retaining, readily penetrable, and highly productive.

The area through which lower Crab Creek flows below O'Sullivan Dam is a scab-land channel resulting from glacial waters removing loessal and lake-bed soils. The scablands are generally covered with a very shallow soil depth and are sparsely vegetated. Large alkaline areas occur along the lower Crab Creek Valley and these soils remain unclassified. There are other areas scattered throughout the project area where basalt is at or near the surface.

The soils suitable for irrigation farming range from fine silt loam to loamy sands from 2 feet to 15 feet in depth.

2. Climate

The arid climate of the project area is characterized by an abundance of sunshine, little precipitation, and relatively mild winters. The average annual precipitation ranges from less than six inches in the southwestern part of the area to slightly less than thirteen inches in the extreme eastern part. Most of the precipitation falls in late autumn as rain and in winter as snow, with very little rainfall in the growing season from April to October.

The temperatures range from an average January minimum of about 20 degrees Fahrenheit to an average July maximum of 91 degrees, with an average annual temperature of about 50.4 degrees. Temperature extremes of 22 degrees below zero and 113 degrees above zero have been recorded. Evaporation rates range from 50 to 60 inches per year.

The average frost-free period for the project area is 166 days, with a range of 127 to 212 days in different sections.

V. WATER RESOURCES OF THE STUDY AREA

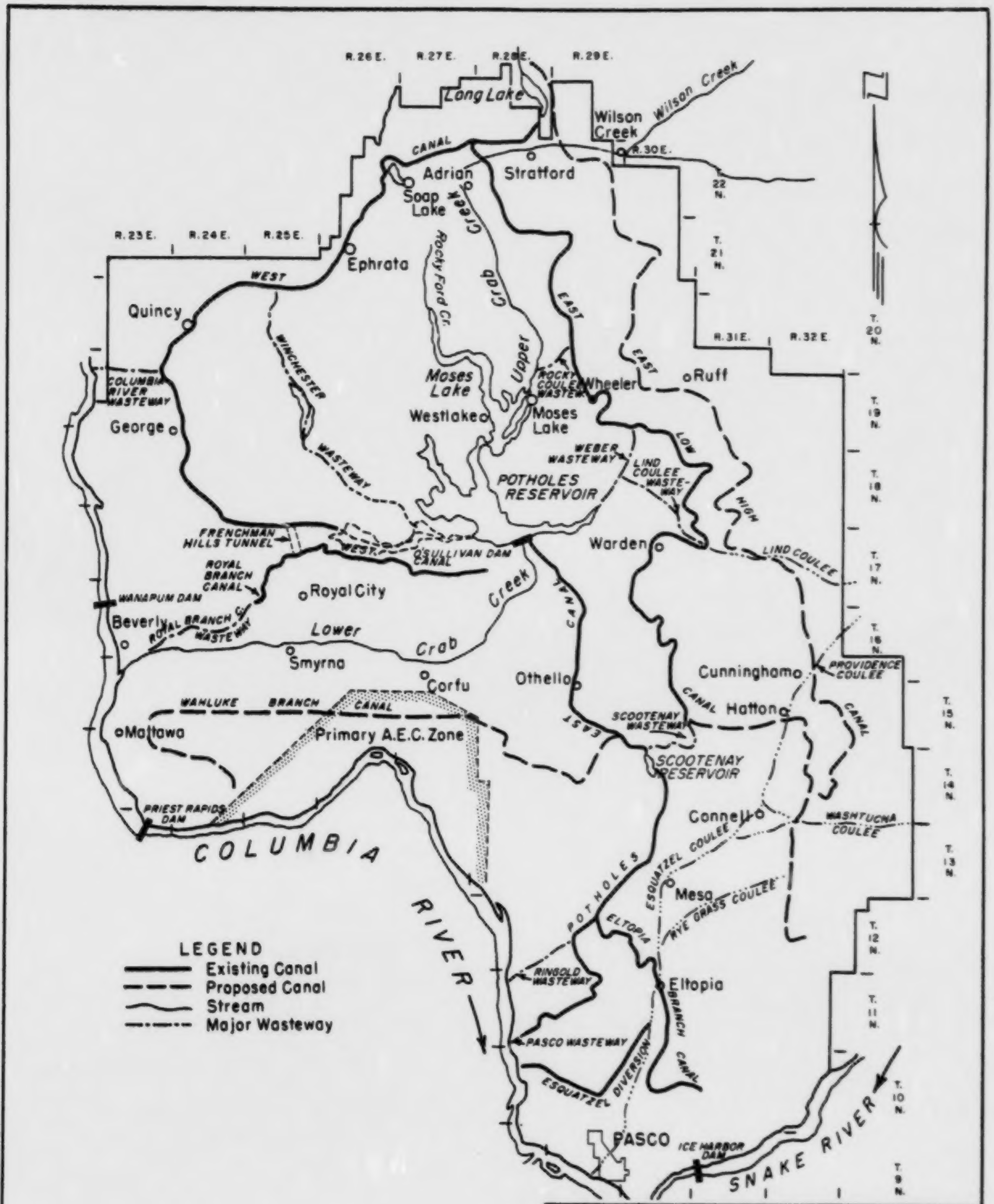
A. General

Since 1952, when irrigation was first introduced to the region, a decided hydrological transformation has taken place. Natural drainageways, which were formerly dry or intermittent, are now flowing year around. Lakes and water holes now exist where dust bowls and dry depressions in the earth once existed. Ground water, formerly deep and difficult to find, now is shallow and abundant in many areas.

Records have been kept of the stream flows in the area, the water levels in some of the lakes, and the amounts of water imported into the area by pumping from the Columbia River behind Grand Coulee Dam. The distribution facilities of the project are shown in Figure 2. Those flows believed pertinent to this investigation, such as inflows and outflows to and from Moses Lake, releases from Potholes Reservoir to Crab Creek, and the quantities of water diverted to project facilities are listed in Appendix A. The quantities of water shown in connection with Moses Lake and Crab Creek are included because of their recreation and fishery significance.

B. Surface Water

The annual diversion of Columbia River water into the project area was more than 1,750,000 acre-feet in 1962. The quantities of water distributed to the area by the project canals at that time are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Long Lake
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CANAL
Adrian
Stratford
Soap Lake
Creek
Ephrata
WEST
Quincy
Rocky Ford Cr.
Crab
Upper
EAST
EAST
COLUMBIA RIVER WASTEWAY
WINCHESTER
WASTEWAY
Moses Lake
ROCKY COULEE WASTEW.
Wheeler
Ruff
Westlake
Moses Lake
George
WEBER WASTEWAY
LIND COULEE WASTEWAY
LOW
HIGH
POTHOLES RESERVOIR
FRENCHMAN HILLS TUNNEL
WEST
O'SULLIVAN DAM
CANAL
Warden
LIND COULEE
ROYAL BRANCH CANAL
Royal City
Creek
CANAL
WANAPUM DAM
Beverly
ROYAL BRANCH C.
WASTEWAY
Lower
Crab
Smyrna
Corfu
Othello
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WAHLUKE
BRANCH
CANAL
CANAL
Hatton
CANAL
Mattawa
Primary A.E.C. Zone
EAST
SCOOTENAY WASTEWAY
SCOOTENAY RESERVOIR
PRIEST RAPIDS DAM
Connell
WASHTUCNA COULEE
COLUMBIA
ESQUATZEL COULEE
POTHOLES
Mesa
RYE GRASS COULEE
RIVER
ELTOPIA
Eltopia
RINGOLD WASTEWAY
PASCO WASTEWAY
BRANCH
CANAL
ESQUATZEL
DIVERSION
PASCO
ICE HARBOR DAM
SNAKE RIVER
LEGEND
Existing Canal
Proposed Canal
Stream
Major Wasteway
6 3 0 6 12
Scale in Miles

WATER SUPPLY and POLLUTION CONTROL STUDY

COLUMBIA BASIN IRRIGATION PROJECT
UPPER COLUMBIA RIVER BASIN, WASHINGTON

PROJECT DISTRIBUTION FACILITIES

U.S. DEPARTMENT OF HEALTH, EDUCATION, & WELFARE
Public Health Service
REGION IX PORTLAND, OREGON

FIGURE 2

shown in Table I, Appendix A. In contrast to this, the surface inflow to Moses Lake from Crab Creek and Rocky Ford Creek (mainly spring fed and partly irrigation return flow) was in the order of 85,000 acre-feet (see Tables 2 and 3, Appendix A). Crab Creek drains an area of about 1,000 square miles outside of the northern boundary of the project area and about 1,000 square miles of the northerly section of the project. Lind Coulee drains to Potholes Reservoir from the central eastern part of the area, and Esquatzel Coulee drains to the Columbia River from the eastern part of the study area south of Lind Coulee. Prior to the project, these were not perennial streams.

Crab Creek, below Potholes Reservoir, now has a fairly constant flow (about 25 cfs) and gains 20 to 30 cfs by the time it reaches the Columbia River. Flows for Crab Creek are shown in Tables 4 and 5, Appendix A. The quality of surface waters in this and other areas of the project is discussed in Chapter VIII.

When the presently authorized Columbia Basin Irrigation Project of 711,000 irrigated acres is completely developed there will be about 3,000,000 acre-feet of Columbia River water imported into the area annually. With the addition of the proposed East High Canal development, a total of 1,097,000 irrigated acres would then be supplied with about 4,400,000 acre-feet of water taken from 79,000,000 acre-feet of the annual mean discharge of the Columbia River at Grand Coulee Dam. Some coulees in the project area will become perennial streams or "pothole" lakes. Additional lakes and reservoirs will become a part of the distribution and water management system.

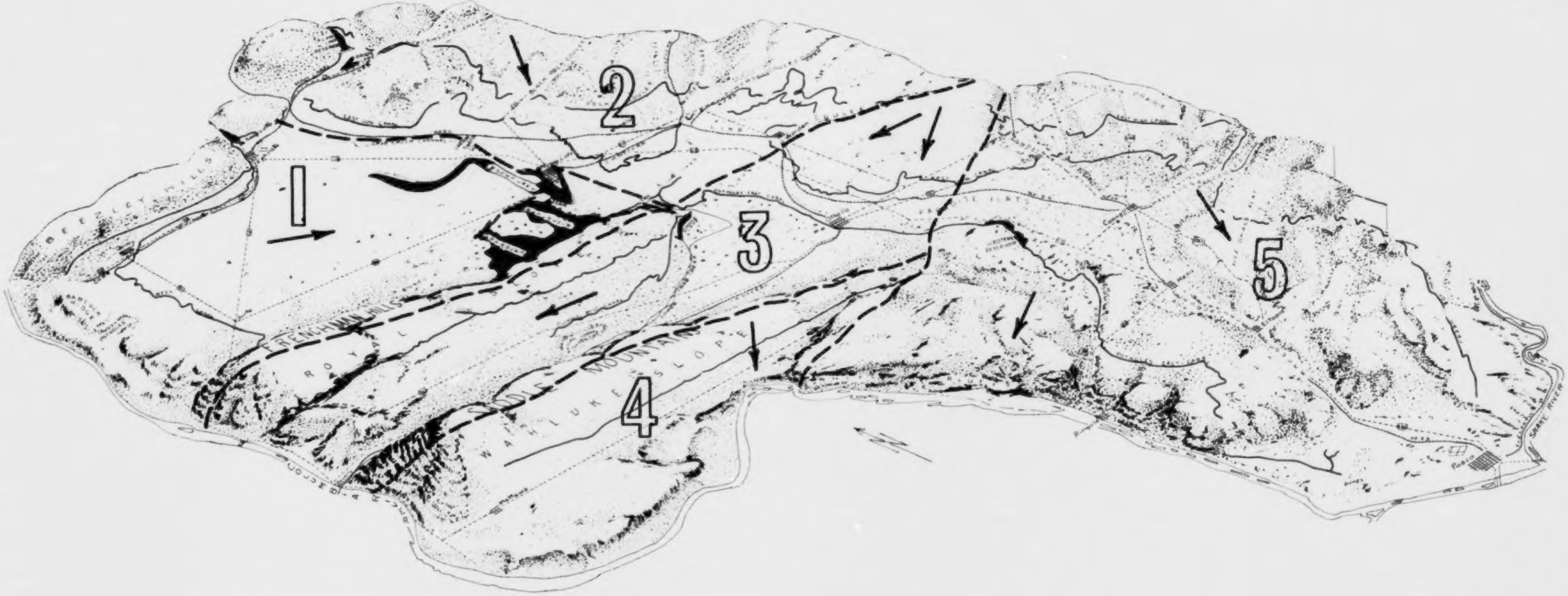
C. Ground Water

Prior to the diversion of water to the irrigation project in 1952, ground water tables varied from surface levels (in potholes or coulees) to depths of more than 800 feet. Ground water tables since 1952 have risen 300 to 500 feet in some places and in others within 30 to 50 feet of the ground surface (Reference X-1). The porous soil permits ready access of precipitation into ground water tables and, because of the arid climate, permitted only limited development for domestic or irrigation use prior to project development. The rise in ground water has necessitated drainage programs in some parts of the project where local sub-surface barriers have blocked the ground water and caused it to surface or "waterlog" the soils.

Although the water table is influenced by many local sub-surface geologic conditions, the total area for study purposes has been divided into drainages which generally conform to surface topography and which are influenced by the visible surface geologic formations. These divisions are shown on the map, Figure 3, and serve as a means for presenting and interpreting the hydrologic and water quality information discussed throughout the report. A description of these inferred drainage areas and their boundaries is given below.

Area 1

This area is located in the northwest part of the study area and is bounded on the north by Beezley Hills, on the west by Babcock Ridge, on the south by Frenchman Hills, and on the east by Crab Creek, Moses Lake, and Potholes Reservoir. The ground surface


1
2
3
4
5
FRENCHMAN HILLS
ROYAL SLOPE
SADDLE MOUNTAINS
WAHLUKE SLOPE
SNAKE RIVER

Modified from map prepared by the
Office of Conservation & Survey Institute of Agricultural Sciences
State College of Washington

WATER SUPPLY and POLLUTION CONTROL STUDY

COLUMBIA BASIN IRRIGATION PROJECT
UPPER COLUMBIA RIVER BASIN, WASHINGTON

GROUND WATER DIVISIONS and
INFERRED DIRECTION of FLOW

U.S. DEPARTMENT OF HEALTH, EDUCATION, & WELFARE
Public Health Service
REGION IX PORTLAND, OREGON

FIGURE 3

and ground water slope is generally to the southeast. About 80 per cent of the lands were developed for irrigation by 1963 and are serviced by the West Canal.

Area 2

This drainage area is in the northeast part of the study area and is bounded essentially by Crab Creek on the north, the eastern uplands and scablands in the east, and by Lind Coulee on the south. The topography and slope is westerly to Crab Creek, Moses Lake, and Potholes Reservoir. A considerable portion of the lands served by East Low Canal and more than one-half of the additional lands to be served by the proposed East High Canal are in this drainage area. About 45 per cent (about 70,000 to 80,000 acre-feet) of the water inflow to Moses Lake is from underground sources originating in this area (Reference X-21).

Area 3

This drainage is bounded by Frenchman Hills on the northwest, Lind Coulee on the northeast, Saddle Mountains on the southwest, and an undefined ground-water divide near Scootenay Reservoir which may drain either to Lind Coulee on the North, Providence Coulee to the east, Scootenay Reservoir to the south, or Crab Creek to the west. The area is characterized by a flat ground water gradient. The drainage slope probably is in a westerly direction toward Crab Creek. About one-forth of the proposed irrigation in this area would occur with the East High Canal development. The lands in this area are served by Potholes West Canal and its Royal Slope Branch, by Potholes East Canal, and by East Low Canal.

Area 4

This area would appear as a wedge with the apex at the ground water divide near Scootenay Reservoir, with a north boundary extending westward along Saddle Mountains and the south boundary extending to the Columbia River in a southwesterly direction. The area is served by Wahluke Branch Canal of the Potholes East Canal. The slope is west and south to the Columbia River.

Area 5

This area comprises the remainder of the project south to the Snake River. The surface drainage is principally to Esquatzel Coulee and its tributary coulees (Providence, Washtucna, and Rye Grass), while the ground water slope is generally southwesterly. The area is served by Potholes East Canal and its branches and East Low Canal. Possibly one-fourth of the lands associated with East High Canal are in the northeast section of this area.

Of the presently authorized 711,000 acres, about 450,000 acres were irrigated in 1963. The greatest share of additional lands to be developed are within the East Low and Potholes East Canal areas (Areas 2, 3, and 5). The East High Canal development of about 386,000 acres is in Areas 2, 3, and 5, as described above.

The quality of ground water in these areas is discussed in Chapter VIII.

VI. ECONOMY

A. General

The demand for water for municipal and industrial purposes, and the amount and character of waste waters resulting from such uses, are determined largely by the activities associated with a region's economic base. The purpose of this section is to present economic and demographic data to be used as a basis for projecting the needs for water for municipal and industrial purposes and for estimating the future amounts and types of waste and land drainage material that may be expected to occur in the Columbia Basin Irrigation Project area with the expanded development anticipated in the future.

B. Present

1. Economic Activities

Agriculture is the most important activity in the project area, and food processing is of growing importance. In addition, the Pasco area derives some support from the nearby Hanford Atomic Works (See Figure 1), and a major ingredient in the economy of the Moses Lake area is Larson Air Force Base. However, during 1964, plans were announced to curtail operations at Hanford and to close the air base.

Employment, by major industry, in the 3-County Area (Adams, Franklin, and Grant Counties), as of April, 1960, is shown in Table VI-1.

The pattern of employment in the project area approximates closely that in the 3-County Area. Table VI-1 also compares the distribution of the labor force among the major industries in the 3-County Area with the distributions in the Spokane region and in the U. S. The comparison shows the importance of agriculture and military activities in the 3-County Area. The relatively high employment in "Utilities and Sanitary Services" and in "Public Administration" is due partly to the importance of irrigation and electric power projects and installations.

The foundation of the agricultural economy is its irrigated acreage, which increased in the project area from 203,000 acres, in 1957, to 346,000 acres, in 1962. Table VI-2 shows how this acreage was distributed among the various crops during recent years.

2. Population

Table VI-3 shows the present population in the "Economic Base Study Area", which is a group of Census Divisions closely approximating the boundaries of the project area. The table also shows the present population in all incorporated places in that area. Historical data are given where available. The table includes population data for the 3-County Area which is used in this study for most economic analysis.

The large increase in population in the unincorporated portion of the study area, from 1950 to 1960, was largely due to an increase in irrigation development during that period. The increase

TABLE VI-1
EMPLOYMENT BY INDUSTRY
COLUMBIA BASIN 3-COUNTY AREA, SPOKANE REGION AND U.S.
APRIL, 1960 (U. S. Census of Population)

Industry	Number Employed Columbia Basin 3-County Area[a]	Percentage Distribution of Total Labor Force		
		Colum. Basin 3-Cty Area[a]	Spokane Region[b]	Total U. S.
Agriculture	4,568	14.5	10.0	6.1
Forestry and fisheries	16	.1	.4	.1
Mining	48	.2	1.6	.9
Manufacturing, Total	2,375	7.5	13.8	25.1
Lumber,wood prod.,furn.& fix.	82	.3	5.2	1.5
Primary & fabricated metals	43	.1	2.1	3.6
Machinery, incl. electrical	228	.7	.8	4.4
Other durable goods	787[c]	2.5[c]	1.2	4.6
Foods & kindred products	335	1.1	2.2	2.6
Textiles and apparel	8	-[d]	-[d]	3.1
Printing, publishing & allied	380	1.2	1.2	1.6
Chemicals and related	403[e]	1.3[e]	.3	1.2
Other non-durables & misc.	109	.3	.8	2.5
Construction	3,552[f]	11.3[f]	6.5	5.5
Railroad transportation	767	2.4	2.2	1.3
Truck transp., warehousing	480	1.5	1.3	1.3
Other transportation	220	.7	.7	1.3
Communications	409	1.3	1.2	1.2
Utilities, sanitary services	916	2.9	1.5	1.3
Wholesale trade	773	2.4	3.7	3.2
Retail trade	4,079	12.9	14.6	13.7
Fin.,Ins.,Real Est.,Bus.& Rep.Serv.	1,343	4.2	5.2	6.2
Pers. serv., incl. ent. & recr.	1,822	5.8	6.7	6.2
Education, public & private	1,644	5.3	6.8	4.8
Professional and related	1,247	4.0	6.4	6.0
Public administration	1,613	5.1	4.5	4.6
Industry not reported	813	2.6	2.1	3.7
Total Emp.Civilian Labor Force	26,705	84.7	89.2	92.5
Military	3,252	10.3	4.1	2.5
Unemployed	1,586	5.0	6.7	5.0
TOTAL LABOR FORCE	31,543	100.0	100.0	100.0

[a] Includes all of Adams, Franklin and Grant Counties.

[b] Includes 15 counties in eastern Wash.& 10 counties in northern Idaho.

[c] Employment in April 1960 in this category included temporary work on missile bases. By April 1963, employment in this category had declined to an estimated 200 or about 0.7 per cent of the total labor force.

[d] Less than .05 per cent.

[e] Includes persons living in or near Pasco, in Franklin Cty., who commute to work at the Hanford Atomic Works in Benton County.

[f] Emp. in Apr.1960 in this category incl. temp. work on missile bases. By Apr.1963, emp. in this category had declined to an est. 1000 or about 3.5 per cent of the total labor force.

TABLE VI-2

TOTAL IRRIGATED LAND AND USE OF IRRIGATED LAND BY CROP ACREAGE COLUMBIA BASIN PROJECT AREA, 1957-60 AND 1962

	Thousand of Acres					
Crop	1957	1958	1959	1960	1961	1962
Wheat	29	41	36	44	45	27
Barley	5	4	6	15	17	12
Corn for grain	4	12	25	24	13	11
Other cereals	4	5	11	10	4	3
Alfalfa hay	54	44	52	75	89	93
Irrigated pasture	7	10	11	12	14	17
Corn silage	2	3	6	6	4	7
Other forage	1	1	3	3	3	2
Beans, dry	40	66	56	40	25	30
Sugar beets	11	12	12	14	27	29
Misc. field crops	1	1	2	3	4	3
Potatoes	17	21	20	21	29	27
Other vegetables	4	3	3	4	7	7
Seeds, pea	17	8	13	14	24	31
Seeds, other	4	4	4	6	8	11
Fruits	--	--	--	1	1	1
All crops	200	235	260	292	314	311
Adjusted for multiple cropping	196	230	255	284	305	305
Irrigated cropland not harvested (soil building, etc.)	7	8	12	10	9	41[a]
TOTAL IRRIGATED ACREAGE	203	238	267	294	314	346

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[a] Consists largely of land in feed grains diversion program of U. S. Department of Agriculture.

Source: Crop Production Reports, Bureau of Reclamation

TABLE VI-3
POPULATION, COLUMBIA BASIN PROJECT ECONOMIC BASE STUDY AREA, INCORPORATED AND UNINCORPORATED PORTIONS, AND 3-COUNTY AREA
1920 to 1963

Incorporated Place or Area	1920	1930	1940	1950	1960	1963
Adams County, part [a]	x	x	x	984	4581	x
Hatton	87	65	43	42	65	63
Othello	649	397	332	526	2669	3271
Unincorporated	x	x	x	416	1847	x
Franklin County, part [b]	x	x	x	13132	22950	x
Connell	311	321	365	465	906	937
Mesa	x	x	x	x	263	260
Pasco	3362	3496	3913	10228	14522	16500
Pasco West [c]	x	x	x	x	2894	3300[d]
Uninc.,excl.Pasco West	x	x	x	2439	4365	x
Grant County, part [e]	x	x	x	16994	43354	x
George	x	x	x	x	x	291
Royal City	x	x	x	x	x	301
Ephrata	628	516	951	4589	6548	7000
Krupp	x	x	x	94	98	99
Mattawa	x	x	x	x	394	265
Moses Lake	x	x	326	2679	11299	11600
Quincy	285	266	318	803	3269	3375
Soap Lake	352	282	622	2091	1591	2100
Warden	173	100	78	322	949	1111
Westlake	x	x	x	x	298	515
Wilson Creek	x	x	x	210	337	252
Unincorporated	x	x	x	6206	18571	x
Walla Walla County,part [f]	x	x	x	885	1087	x
Unincorporated	x	x	x	885	1087	x
TOTAL INCORP. PLACES	5847	5443	6948	22049	46102[g]	51240
TOTAL UNINCORP. PORTIONS OF EC. BASE STUDY AREA	x	x	x	9946	25870[g]	x
TOTAL EC.BASE STUDY AREA	x	x	x	31995	71972	x
PORTIONS OF ADAMS, FRANKLIN & GRANT COUNTIES NOT INCL. IN EC. BASE STUDY AREA	x	x	x	13383[h]	8863[h]	x
TOTAL POPULATION, 3-COUNTY AREA [i]	23271	19522	27184	44493	79748	x

(See Next Page for Footnotes)

TABLE VI-3 (continued)

a/ Adams County Census Divisions 4, 9 and 10 are included in the economic base study area.

b/ All of Franklin County, with the exception of Census Division 1, is included in the economic base study area.

c/ Pasco West is a densely built up suburb (unincorporated) of Pasco which was designated for separate enumeration in 1960 by the U. S. Census Bureau.

d/ An official estimate for "Pasco West" was not available for 1963. For this table, it has been assumed that "Pasco West" increased at the same rate as the City of Pasco during the period 1960-63.

e/ All of Grant County is included in the economic base study area with the exception of the following Census Divisions: 1, 2, 3, and 8.

f/ Walla Walla County Census Division 3 is included in the economic base study area.

g/ The suburb of Pasco called "Pasco West" in 1960 Census Report is included in the total for incorporated areas and excluded from the total for the unincorporated portions.

h/ The decrease in population was due primarily to the termination of temporary employment on construction projects.

i/ The portion of Walla Walla County included in the economic base study area is not included in the 3-County Area.

x/ Not available.

SOURCES: Figures for 1920 through 1960 are from the U. S. Census of Population, which was taken as of January 1, in 1920, and as of April 1, in 1930, 1940, 1950 and 1960.

Figures for 1963 are estimates by the Washington State Census Board for April 1, 1963.

in population in the incorporated places during the 1950-60 decade was due to the impact of increased basic employment resulting from such activities as the Hanford Atomic Works, the Larson Air Force Base, and the establishment of several food processing plants.

Population in the economic base study area increased about 40,000 during the 1950-60 decade or more than a doubling. All of the population growth in the 3-County Area, during the 1950-60 decade, occurred in the economic base study area; population in the portions of the 3-County Area outside the economic base study area declined during the decade.

3. Land Uses

The 3-County Area contains a total of 3,741,000 acres. Of these, 2,745,000 acres, or about 73 per cent, were in farms at the time of the 1959 Census of Agriculture. The uses of the land in farms, in 1959, are shown in Table VI-4. Of the 3-County Area, about 1,097,000 acres are within the project area. Of these, about 346,000 acres were irrigated in 1962. Table VI-5 shows land use in the project area in 1962.

C. Factors Influencing Future Growth

1. Acreage

It is assumed here, in line with Bureau of Reclamation plans, that project irrigation facilities will be completed by about 1985. Full development of irrigable acreage in the project area will not be completed until some years after that. It is assumed here that

TABLE VI-4
LAND USE IN THE COLUMBIA BASIN 3-COUNTY AREA
1959

Use of Land	Thousands of Acres
Cropland harvested	875
Cropland used for pasture	67
Cropland idle (summer fallow, soil building cover, etc.)	717
Woodland used for pasture	11
Woodland not used for pasture	9
Improved pasture	11
Other pasture	960
House lots, roads, wasteland, etc.	95
Total land in farms	2,745
Portion of 3-County Area not in farms	996
TOTAL 3-COUNTY AREA	3,741

Source: U. S. Census of Agriculture, 1959.

TABLE VI-5
USES OF IRRIGABLE LAND
COLUMBIA BASIN PROJECT AREA
1962

Use of Land	Thousands of Acres
Irrigated land:	
Harvested cropland and pasture	305
Cropland not harvested (soil building, fallow, idle)	41
TOTAL IRRIGATED LAND	346
Irrigable land not irrigated in 1962:	
Idle, fallow or grazed	94
Farmsteads, roads, ditches, etc.	13
TOTAL PROJECT SERVICE AREA	453

Source: Bureau of Reclamation Crop Production Report, 1962.

the project area will be fully developed by 2010, which would mean that irrigated acres would increase from about 346,000, in 1962, to 1,097,000 in 2010. On the basis of the blocks scheduled for development by the Bureau of Reclamation, it is assumed that, by 1985, developed acres will total 960,000.

2. Food Processing

Employment in food processing plants increased substantially during the three years from 1960 to 1963. It is estimated that employment in that category in April, 1963, was about 700, compared with 335 in April, 1960. It is assumed that production of raw materials for food processing plants will increase more rapidly than total acreage. For purposes of this estimate, it is assumed that output from food processing plants, in 1985, will be about five times what it is at present and, in 2010, about seven times what it is at present.

3. Military

Military employment at Larson Air Force Base is a major factor at present in the economic base of the project area. Since plans were announced, in 1964, to close this establishment over the next few years, the future of this component of the economic base is problematical. However, it is assumed here that, even if air force operations are discontinued, the facilities will attract some allied use associated with aviation or aerospace and that employment, in 1985 and 2010, will be about what it is now, though there may well be a dip in employment in this category during the next decade.

4. New Basic Industries

Some possibilities for new industries include manufacturing of specialized equipment used in farming and irrigation, preparation of chemicals used in agriculture, and the development of mineral deposits in the 3-County Area, which could provide modest employment in extractive industries. Industrial development will be facilitated by the fact that good barge transportation is available at Pasco and may be extended to Wenatchee. As population and industry increase in the area, providing a larger market, it will become economic to produce locally goods which are, at present, brought in from other centers.

5. Service Industries

Employment in service industries relative to total employment will increase not only because of well-established national trends in this direction, but also because, as population density in this area increases, some of the services, which are now provided by regional centers such as Spokane, will be available locally.

6. National and State Population Growth

It is assumed that U. S. population growth during 1960 to 2010 will approximate the U. S. Census Bureau's "Series A" projection (an increase of about 1.8 per cent per year) and that population in Washington State will increase at about 2.0 per cent per year during the next fifty years.1/

1/ These rates correspond to the assumptions adopted by the CBIAC Economics Subcommitte in May, 1964.

D. Future

1. Economic Activities

On the basis of the preceding considerations, Table VI-6 presents a judgmental projection of the labor force in the 3-County Area, in 1985 and 2010, and an estimate of the population which could be supported by that employment.

2. Population

On the basis of the projected labor force, Table VI-6 shows an estimate of the population in the 3-County Area, in 1985, at 175,000, with an increase to 273,000 by 2010.

Population in the economic base study area represents the largest part and an increasing proportion of population in the 3-County Area. Population in the economic base study area was about 72 per cent of the 3-County Area population, in 1950, and about 90 per cent in 1960. Because the expansion of irrigated acreage within the project area will be the chief impetus to growth in the 3-County Area in the future, it is assumed that this percentage will continue to increase, consistent with the recent trend in rate. It is assumed, for purposes of this forecast, that population in the economic base study area will represent 93 per cent of 3-County Area population, in 1985, and 95 per cent in 2010. This would mean that, on the basis of the projected 3-County Area population shown in Table VI-6, population in the economic base study area (and the project area) would be (in thousands): 1950, 32.0; 1960, 72.1; 1985, 163; 2010, 259.

TABLE VI-6

PROJECTED LABOR FORCE AND POPULATION
COLUMBIA BASIN 3-COUNTY AREA
1985 & 2010

Industry	Thousands, as of April 1963 a/	 1985	 2010
Agriculture	5.0	10.0	12.0
Forestry, fisheries, mining	0.1	0.5	1.0
Manufacturing, Total	3.2	9.0	17.0
Total - Ag., Extractive and Mfr.	8.3	19.5	30.0
Construction	1.0	3.3 b/	5.1 b/
Military	3.3	3.3	3.3
Total employment other than services	12.6	26.1	38.4
Services as % of all other employment	143%	156% c/	170% c/
Services d/	18.0	40.7	65.2
Total Employment	30.6	66.8	103.6
Unemployed	1.6	3.5 e/	5.5 e/
TOTAL LABOR FORCE	32.2	70.3	109.1
Population as % of Total Labor Force	250%	250%	250%
Estimated Population	80	175	273

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a/ Estimated as derived from "Covered Employment" figures from Washington State Depart. of Employment Security and from 1963 population estimates of Washington State Dept. of Health.

b/ Derived by assuming that construction will be the same percentage of total employment in agriculture + extractive industries + manufacturing, as it was in the U.S. as a whole in 1960; that is 17%.

c/ The ratio assumed for 1985 is the same as that in the Spokane region in 1960. The ratio of services to other employment has been increasing in recent decades, and it is expected to continue to increase at about the same relative rate.

d/ Includes "industry not reported", about 2% of the total labor force.

e/ Assuming the ratio of unemployment to employment is the same as it was in the 3-County Area, in 1960 and 1963, and in the U.S. as a whole in 1960; that is, about 5.3%.

As shown in Table VI-7, the proportion of total population within the economic base study area in incorporated places declined from about 69 per cent, in 1950, to about 64 per cent in 1960. This was due to the rapid expansion in irrigated acreage and in farm population. During the 1960 to 2010 study period, expansion of irrigated acreage and farm population will continue. However, diversified manufacturing and other urban activities are also expected to increase, so it is assumed that the proportion of population in incorporated areas will increase by 1985 to about the ratio existing in 1950. After 1985, the rate of growth in farm population will decline. Rural non-farm and suburban population will continue to increase moderately. Therefore, most of the growth in population during the 1985 to 2010 period will occur in incorporated areas, and the proportion in incorporated places will rise more markedly. On the basis of these assumptions, the distribution of population between incorporated and unincorporated portions of the economic base study area (and the project area) might be expected to approximate that shown in Table VI-7.

TABLE VI-7
COLUMBIA BASIN ECONOMIC BASE STUDY AREA
PROPORTION OF POPULATION IN INCORPORATED AND UNINCORPORATED AREAS
1950 - 2010

	Population, in thousands			
	1950	1960	1985	2010
Incorporated places, total population	22	46	112	201
Unincorporated - including farm, rural non-farm and suburban	10	26	51	58
Total population, economic base study area	32	72	163	259
Percentage of total population in incorporated places	69%	64%	69%	78%

For purposes of projecting future water supply requirements and factors affecting water quality problems, the economic base study area has been divided into seven sub-areas. These sub-areas have been delineated on the basis of topographical, drainage and land use considerations, as adjusted to conform to County Census Division boundaries. Table VI-8 shows the projected 1985 and 2010 population for the incorporated and unincorporated portions for each of these sub-areas.

An estimate of 1985 and 2010 population in each incorporated place in the economic base study area is given in Table VI-9. For planning purposes, such assumptions regarding the future populations of the area's cities are necessary, but it must be emphasized that they are provided only as arbitrary estimates of what the cities' future populations might reasonably be expected to be. In estimating the growth of the smaller cities, the amount of projected irrigation development around them has been a primary consideration. It is assumed that the increase in diversified manufacturing and services projected for the economic base study period will tend to be concentrated in the larger cities.

TABLE VI-8
COLUMBIA BASIN ECONOMIC BASE STUDY AREA
PROJECTED POPULATION, INCORPORATED & UNINCORP. PORTIONS, BY SUB-AREA
1985 - 2010

Sub-Area	Census County Divisions Include a/	Irrigated Blocks Include b/	Developed Irrigated Acres thousands			Population, in thousands								
						Incorporated Places c/			Outside Incorporated Places			Total		
			1963	1985	2010	1960	1985	2010	1960	1985	2010	1960	1985	2010
1	G17	26, 252 251,25,27	0	46	46	.4	2	2	.2	2	2	.6	4	4
2	G16	80,82,83,85, 86,87,88, 881,81, 84	58	96	96	0	2	2	1.1	3	3	1.1	5	5
3	G6, G7, G9, G10, G11, G12, G14, G15, Ephrata	70,701,72, 73,74,75, 76,77,78, 79,71,89, 40,41,42, 421,43,44 741, Q(pt)	179	257	257	24.0	56	99	16.7	20	20	40.7	76	119
4	G4, G5	A,B,C(pt), D(pt), 90, 91	0	43	43	.4	2	2	.3	2	2	.7	4	4
5	G13	C(pt), D(pt), E,F,G,H,J, K(pt)	0	92	92	0	0	0	.3	4	4	.3	4	4

(Continued, Next Page)

TABLE VI-8 (continued)

Sub-Area	Census County Divisions Include a/	Irrigated Blocks Include b/	Developed Irrigated Acres thousands			Incorporated Places c/			Outside Incorporated Places			Total		
			1963	1985	2010	1960	1985	2010	1960	1985	2010	1960	1985	2010
6	A4, A9, A10	45,46,47 49,48,491, 55,50, R, S,N, K(pt), L, Q(pt), 36,M,O,P, T,U,V,W,X, Y, Z(pt)	42	175	306	2.7	9	20	1.9	8	14	4.6	17	34
7	F2, F3, F4, F5, Pasco, W3	11,18,12, 13,14,15, 16,1,19, 20,23,201, 2,3,17,33, 30,29,35, 28,21, Z(pt)	101	251	257	18.6	41	76	5.5	12	13	24.1	53	89
TOTAL, ECONOMIC BASE STUDY AREA			380	960	1097	46.1	112	201	26.0	51	58	72.1	163	259

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a/ Prefix G represents Grant City; A, Adams City; F, Franklin City; and W, Walla Walla City. Some irrigation blocks lie outside but adjacent to the Census Divisions shown.

b/ As shown on Bureau of Reclamation's Columbia Basin Project Development Schedules.

c/ For list of incorporated places included in each sub-area, see Table VI-9.

TABLE VI-9
COLUMBIA BASIN ECONOMIC BASE STUDY AREA
ESTIMATED POPULATION IN INCORPORATED PLACES
1985 and 2010

Incorporated Place By Sub-Areas Shown in Table VI-8	1960 Population (nearest thousand)	Estimated Population (in thousands)	
		1985	2010
Sub-Area 1:			
Mattawa	0.4	2	2
Sub-Area 2:			
Royal City	(0.3) [a]	2	2
Sub-Area 3:			
Ephrata	6.5	16	29
George	(0.3) [a]	1	2
Moses Lake	11.3	25	46
Quincy	3.3	6	9
Soap Lake	1.6	4	6
Warden	0.9	3	5
Westlake	0.3	1	2
Sub-Area 4:			
Krupp	0.1	-- [b]	-- [b]
Wilson Creek	0.3	2	2
Sub-Area 5:			
None			
Sub-Area 6:			
Hatton	0.1	1	1
Othello	2.7	8	19
Sub-Area 7:			
Connell	0.9	4	6
Mesa	0.3	1	2
Pasco[c]	17.4	36	68
TOTAL, ALL INCORP. PLACES	46.1 [d]	112	201

---

[a] Estimated 1963 population unincorporated in 1960.

[b] Less than 500.

[c] Includes unincorporated suburban area identified in 1960 U.S.Census of Population as "Pasco West".

[d] Excludes Royal City and George, unincorporated in 1960.

3. Future Land Uses

It is assumed here that the only significant change in land use, from the standpoint of water quality, will be the increase in irrigated acreage during the study period. Irrigated land totaled 346,000 acres, in 1962; 380,000 acres, in 1963; and is projected to reach 960,000 acres in 1985 and 1,097,000 acres by 2010. This would represent a transfer of land from dry farming or from non-use to irrigation.

4. Projected Population Without Development of the East High Canal

The preceding projections have been predicated on the assumption that the East High Canal will be built in accordance with the present Bureau of Reclamation plans. If the East High Canal were not built, Sub-Areas 4, 5, and 6 (as identified in Table VI-8) would have very little development. Development in the other sub-areas would be about the same as that shown in Table VI-8 even without the East High Canal.

It is estimated that without the East High Canal only about 6,000 acres would be developed in Sub-Area 4 by 1985 and there would be no further development after 1985. In Sub-Area 5 there would be no development without the East High Canal. In Sub-Area 6, developed land in 1985 would be about 50,000 acres; and, in 2010, about 63,000 acres. On this basis, it is estimated that total population in the three affected sub-areas would be as follows:

	1985		2010	
Sub-Area	With EHC*	Without EHC*	With EHC*	Without EHC*
4	4,000	1,000	4,000	1,000
5	4,000	0	4,000	0
6	17,000	8,000	34,000	10,000
TOTAL	25,000	9,000	42,000	11,000

*EHC = East High Canal

In addition to these effects felt directly in Sub-Area 4, 5, and 6, population in the principal cities of the study area (Ephrata, Moses Lake, and Pasco) would also be smaller, since the support for service industry employment and the supply of raw material for food processing would both be less. It is assumed here, for purposes of deriving design figures, that the total reduction of urban population in the three principal cities would be about half the direct decrease in population in the immediately affected sub-areas. Pasco would probably be affected somewhat less than Moses Lake and Ephrata. On this basis, judgmental estimate of what future population in the four incorporated places in Sub-Areas 4, 5, and 6, and in Moses Lake, Pasco, and Ephrata might be without development of the East High Canal is as follows:

CITIES AFFECTED	POPULATION (in thousands)			
	1985		2010	
	With EHC*	Without EHC*	With EHC*	Without EHC*
Incorporated Places in Sub-Areas 4, 5, and 6				
Krupp	a/	a/	a/	a/
Wilson Creek	2	a/	2	a/
Hatton	1	a/	1	a/
Othello	8	5	19	6
Ephrata	16	14	29	25
Moses Lake	25	22	46	41
Pasco	36	33	68	62

---

*EHC = East High Canal
a/ Less than 500.

Without the East High Canal, then, total population in the economic base study area, in 1985, would be 139,000, instead of the 163,000 shown in Table VI-8 for full development. Of the 24,000 difference, lack of development in Sub-Areas 4, 5, and 6 would account for 16,000 and smaller population in Ephrata, Moses Lake, and Pasco would account for 8,000. In 2010, total population in the study area without the East High Canal would be 213,000, instead of the 259,000 projected in Table VI-8 for full development. Of the 46,000 difference, lack of development in Sub-Areas 4, 5, and 6 would account for 31,000, and smaller population in Ephrata, Moses Lake, and Pasco for 15,000.

VII. WATER REQUIREMENTS--DOMESTIC, MUNICIPAL & INDUSTRIAL

A. Past and Present Water Use

1. General

Developed surface and ground water sources within the Columbia Basin Irrigation Project area serve rural domestic, municipal and industrial needs amounting to approximately 22,500 acre-feet per year. Ground water sources provide about 17,500 acre-feet of this demand, and surface water sources supply the remaining 5,000 acre-feet.

In 1963, seventeen cities served about 30,400 people with water mainly from underground sources, while Pasco, utilizing water from the Columbia River, served a population of 16,000. Four industries use ground water as a source of supply. Table VII-1 summarizes the populations, sources of water and annual use of water for domestic, municipal and industrial purposes in the study area.

TABLE VII-1
1963 WATER USES AND SOURCES

	Population (1) or Industry (2)	Source	Annual Acre-Feet
Ground Water			
Rural Domestic	28,000 (1)	6000-7000 wells	1,900
Larson AFB (Domes.)	5,000 (1)	Wells	670
Municipal	30,400 (1)	40-50 wells	9,150
Industrial	4 (2)	Wells	5,800
Surface Water			
Municipal	16,000 (1)	Columbia River	5,050

2. Rural Domestic

Exact data on rural domestic water use in the project area are not readily obtainable. Based on a range of 50 to 75 gallons per capita per day (GPCD), suggested by the U. S. Public Health Service Manual of Individual Water Supply Systems, it is estimated that about 60 GPCD are used for rural domestic purposes. Data on individual wells (type, depth, diameter, water-bearing material, water level, type and horsepower of pump, and use) are presented for several thousand wells in another publication (X-1).

3. Municipal Supplies

Table VII-2 summarizes data on municipal water sources, population served, water use and plant capacity. Water consumption records available on eleven cities showed an annual average consumption of 265 GPCD. By use of the above figures and available monthly records, Figure 4 was developed to show the approximate nature of the monthly municipal demands throughout the year.

Seven small communities (Wheeler, Stratford, Adrian, Smyrna, Winchester, Corfu, Ruff), with a total population of 335, are not served by community water supplies.

Two of the seventeen towns using ground water as the primary source of supply use some surface water. Ephrata has used up to 0.5 million gallons per day (MGD) from the West Canal to meet peak summer demands for which the current pumping capacity on the ground water is inadequate. The canal water is screened and chlorinated prior

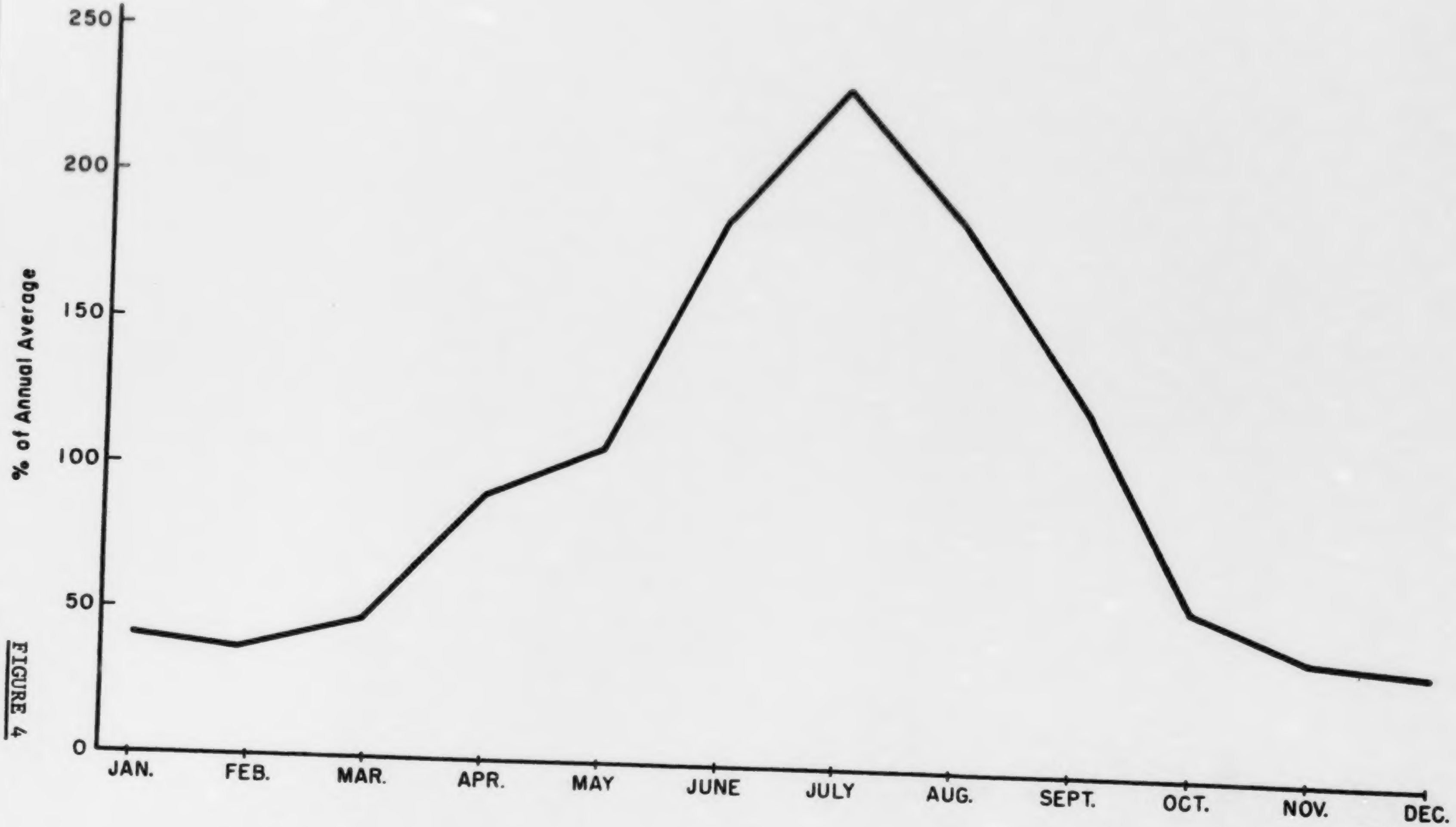
TABLE VII-2
SUMMARY OF MUNICIPAL WATER SUPPLY DATA
COLUMBIA BASIN IRRIGATION PROJECT
1963

Area No.	Town	Source	Pop. Served	Water Use						Plant Capacity MGD
				Average Annual		Maximum Month		Maximum Day		
				MGD	GPCD	MGD	GPCD	MGD	GPCD	
1	Ephrata	6 Wells &	--	--	--	4.37	--	5.60	--	4.38
		West Canal	7,000	2.11	302	0.40	680	0.50	870	1.33
1	Moses Lake	5 Wells	10,500	3.0	284	6.7	640	8.1	770	12.8
1	Quincy	2 Wells	3,400	0.53	155	1.23	362	1.50	441	3.56
1	Westlake	Well	500	0.13	265	0.31	620	0.40	795	1.15
1	Soap Lake	2 Wells & Soap Lake	2,340	0.62	265	1.45	620	1.86	795	1.59
1	George	2 Wells	190	0.05	265	--	--	--	--	--
2	Wilson Cr.	2 Wells	270	0.07	265	0.17	620	0.21	795	0.96
3	Warden	4 Wells	1,200	0.30*	250*	0.70*	585*	0.90*	750*	1.65
3	Royal City	Well	400	0.11	265	0.25	620	0.32	795	0.72
3	Beverly	Well	25	0.007	265	--	--	--	--	--
3	Othello	3 Wells	3,000	0.73	243	1.70	569	2.22	740	3.17
4	Mattawa	Well	150	0.04	265	--	--	--	--	--
5	Eltopia	Well	150	0.04	270	0.072	480	0.122	810	0.072
5	**Mesa**	Well	290	0.071	245	0.17	570	0.213	735	0.36
5	Connell	4 Wells	910	0.29	315	0.49	540	0.64	705	1.29
5	Pasco	Columbia R.	**16,000**	4.40	279	10.23	648	13.9	882	19.5
5	Hatton	Well	75	0.02	265	0.04	620	0.06	795	0.08
5	Cunningham	Well	22	0.006	265	0.01	620	0.02	795	--
	TOTAL		46,422	12.55 = 14,200 Acre-Feet Per Year						
	GROUND WATER		30,422	8.15 = 9,150 Acre-Feet Per Year						

*Excluding industrial demand.

FIGURE 4

COLUMBIA BASIN IRRIGATION PROJECT
Typical Monthly Municipal Water Consumption
1962



to use. A new well is being drilled, and an engineering study of the distribution system was completed in 1963. It is possible that the new well may eliminate the need for canal water for the next few years. The City of Soap Lake pumps water from the highly mineralized Soap Lake for "mineral baths" in many homes and some commercial establishments. The lake water is distributed through a system separated from the ground water distribution system.

The only city in the project which treats ground water prior to use is Quincy. Splash trays are used to remove the excessive amounts of gas found in the well waters before the water enters the distribution system.

Moses Lake recently drilled a new well which increased the capacity of the ground water supply to 12.8 MGD. The need for more storage capacity is of concern to the city and its construction will probably be the next major addition to the water system.

About 5,000 people residing on Larson Air Force Base are served by a ground water supply. The average daily use is estimated at 0.59 MGD.

One of the two wells (pumping capacity of 0.72 MGD) in the Wilson Creek system is used exclusively for lawn and garden irrigation. The well used for domestic purposes was tested at 4.3 MGD when it was drilled several years ago. It is currently equipped with a pumping capacity of 0.24 MGD, which is adequate for the present demands.

One of the wells at Warden, which provides nearly one-half of the total capacity of the system, is used primarily for potato processing. The potato plant is closed during June and July, thus making this supply available to meet the peak municipal demands of July. As noted in Table VII-2, the industrial demand was not included in the per capita demand values for Warden.

At Othello, a 1.4 MGD industrial supply, in addition to the 3.17 MGD supply shown in Table VII-2, is tied into the City system for use during peak municipal demand periods or for emergencies. The City is considering drilling another well in the near future.

The water system in Mesa is privately owned and the City is now preparing to purchase it. Although the current ground water supply is adequate, consideration is being given to combining the City system and a separate U. S. Bureau of Reclamation well supply, serving several government residencies, in order to have an auxiliary supply available.

Pasco is the only city within the project boundaries which uses exclusively a surface water supply, the Columbia River. A filtration plant treats the raw water by means of the Pitman-Conley filtration process. Pre- and post-chlorination are practiced.

Westlake is planning to serve the Mae Valley Water District with water from the Westlake system in the near future. A 100,000 gallon storage tank will be added to the system before such service is established since the current 2,000 gallons of storage would be inadequate.

4. Industrial

Three of the four major industrial users have their own well supplies; and the fourth, Country Gardens, obtains water from the municipal supply at Warden. Although the latter is supplied by a city-owned well, the well is solely for use of the plant during its period of operation (August through May).

TABLE VII-3
INDUSTRIAL WATER USES

Ground Water	Use per Operating Day*	Average Annual Use*	Annual Use (Acre-Feet)
Menan Starch, Moses Lake	1.1	0.92	1,010
Utah Sugar, Moses Lake	3.20	2.65	3,000
Country Gardens, Warden	0.55	0.46	520
Chef Ready, Othello	1.40	1.15	1,300

*Million gallons per day (MGD).

B. Future Needs

Forecasts of future urban and rural water supply needs are based primarily on economic base and population studies (Chapter VI), and the unit demands and uses previously described.

Table VII-4 summarizes projected domestic, municipal and industrial water needs for 1985 and 2010. The only projected use of Columbia River water is for municipal supply at Pasco. It is expected that industrial water requirements for food processing will increase in proportion to the increase in irrigated acres. Food processing predictions assume that crop yields per acre will increase at about the national average or 2 per cent per year until 1985 and about 1 per

TABLE VII-4

FUTURE WATER SUPPLY REQUIREMENTS IN THE COLUMBIA BASIN IRRIGATION PROJECT

Use	Source	1985				2010			
		Population	Ave. GPCD	Ave. MGD	Annual Acre-Feet	Population	Ave. GPCD	Ave. MGD	Annual Acre-Feet
Municipal	Ground*	81,000	290	23.5	26,500	138,000	310	42.8	48,500
Municipal	Surface	36,000	290	10.4	11,800	68,000	310	21.0	23,800
Rural Domestic	Ground	46,000	60	2.8	3,200	53,000	60	3.2	3,600
Industrial	Ground	---	---	23.6	26,700	---	---	32.0	35,200

---

*Includes domestic demand of Larson Air Force Base.

cent per year for the 1985-2010 period. It is assumed that beet and potato production will increase with increased land development in the same acreage proportions as presently exist.

The future municipal per capita water demand is assumed to increase slightly as the project area population increases and the living standards continue to improve. There are little historical data upon which to base such projection; however, data on other cities in Eastern Washington and Oregon indicate that an increase of 8 to 10 per cent in a twenty-five year period would be reasonable.

Based on these assumptions and population forecasts, the total ground water supply requirement by 1985 is expected to be 56,400 acre-feet per year, and the total surface water requirement 11,800 acre-feet per year. Out of the total requirement of 68,200 acre-feet by 1985, industrial constitutes 26,700; rural domestic 3,200; and municipal 38,300 acre-feet.

By 2010, the industrial demands will have increased to 35,200 acre-feet per year, municipal demands to 72,300 acre-feet, and rural domestic demands to 3,600 acre-feet. Out of the total 2010 demand of 111,100 acre-feet, about 78,300 acre-feet are expected to be supplied by ground water.

Without the East High Canal, the total demand would be about 51,000 acre-feet in 1985 and 86,500 acre-feet in 2010.

With replenishment of ground water by the project, this source would provide ample water for all anticipated future uses. The Columbia River will be adequate to meet the increased demands at Pasco.

Table VII-5 outlines the capabilities of present municipal water systems to meet maximum daily and monthly demands. Dates for increased capacity are based upon maximum daily or monthly demands and the assumption that future industries will be self-supplied. A large industrial demand placed on any of the municipal systems would necessitate expansion at earlier times. Soap Lake, Ephrata, and Eltopia have the most urgent needs for facility expansion. Several other cities could meet demands by increasing storage capacities prior to the dates shown in Table VII-5. Ephrata is currently drilling a new well to relieve supply problems and reduce a dependency upon canal water during the summer.

An alternative to the use of ground water is the possible use of water delivered from project facilities. As discussed in detail later in this report, canal water, for example, generally has a lower mineral content. Water treatment costs, however, would be involved in the use of this water. The Washington Department of Health has specified screening and chlorination as the minimum treatment for such water in the upper portion of the project and requires filtration in addition to this in the southern portion of the project. Should ground water quality become unsatisfactory because of pesticides, herbicides, or other contaminants, it is believed that a change in source could be accomplished by means of an exchange of ground water for surface water from the project, thus utilizing the higher quality surface water for domestic, municipal and industrial use and utilizing the ground water for irrigation use.

TABLE VII-5

CAPACITIES OF PRESENT MUNICIPAL WATER SYSTEMS
COLUMBIA BASIN IRRIGATION PROJECT

Area	Town	Present Pop. Served	Present Source Cap. (MGD)	Storage Capacity (MG)	Max. Day Capacity (MGD)	Population Capacity (Max. Day)	Population Capacity (Max.Month)	Date of Increase*
1	Moses Lake	10,500	12.8	3.2	16.0	20,800	20,000	1977
1	Westlake	500	1.15	0.002	1.152	1,450	1,850	1990
1	Soap Lake	2,340	1.59	0.40	1.99	2,500	2,560	1964
1	Ephrata	7,000	5.69	5.5	11.19	12,800	8,300	1965
1	Quincy	3,400	3.56	1.1	4.66	10,600	9,800	--
2	Wilson Creek	270	0.96	0.13	1.09	1,370	1,500	1977
3	Warden	1,200	1.65	0.80	2.45	3,300	2,800	1982
3	Othello	3,000	3.17	1.09	4.26	6,300	5,600	1974
3	Royal City	400	0.72	0.04	0.76	960	1,160	1970
5	Eltopia	150	0.072	0.07	0.142	175	150	1963
5	Mesa	290	0.36	0.10	0.46	625	630	1972
5	Connell	910	1.29	0.28	1.57	2,230	2,390	1972
5	Pasco	16,000	19.5	6.1	25.6	29,000	30,000	1977
5	Hatton	75	0.08	0.10	0.18	225	130	1970

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*Anticipated date of needed increase in capacity.

VIII. WATER QUALITY CONTROL

A. Need for Control

1. Domestic, Municipal, and Industrial Water Supply

The major uses of water in the study area for which a high quality of water is important are uses for domestic, municipal, and industrial food-processing purposes. The extent of these uses and future needs for these purposes were discussed in the previous section.

2. Fisheries and Recreation

The waters of the irrigation project make a substantial contribution to recreation. The U. S. Fish and Wildlife Service (X-22) reports the following fisherman use of project waters:

Type of Water Area	Fisherman Days' Use	Species Fish Stocked
35 pre-project lakes and streams	325,000	Trout, kokanee, and spiny-rays
6 reservoirs created by project	180,000	Trout, bass, burbot, sunfish, whitefish, and walleye
71 new lakes created by project	113,700	Trout
9 wasteways, drains, canals, diversions, and other waterways created by project	11,000	Trout and spiny-rays

The Fish and Wildlife Service reports that many lakes that were too alkaline to support fish life were freshened to the point where they could maintain fish following the initiation of irrigation.

Waterfowl hunting has increased by 600 percent in the last ten years due to the abundance of food and water (X-22). The waterfowl habitat created by the project is expected to be many times the value of the habitat inundated or otherwise destroyed by project development (X-22).

The flows at Ringold Wasteway have increased as a result of the project and are now used on an experimental basis for propagation of chinook salmon and steelhead trout. Return flows to Crab Creek and the appearance of springs have caused an improvement of the fishery habitat.

In addition to fishing, Potholes Reservoir and Long Lake provide facilities for water-based recreation, such as swimming, boating, and related shore activities.

3. Irrigation

Water quality for irrigation is not as stringent as that required for human consumption or for propagation of fish and other aquatic life. It is important, however, that the mineral quality be satisfactory and that conditions which promote excessive biological activity and which thus interfere with normal operation of the system be minimized. The importance and magnitude of irrigation development existing and proposed are described in Chapter III.

B. Municipal, Industrial, and Agricultural Pollution

1. Present

a. General

Wastes produced within the project area consist of domestic sewage, potato-processing wastes, beet-processing wastes, and used water resulting from irrigation. A few small milk-processing plants, small meat-processing plants, and a corn-processing plant discharge wastes to city sewer systems. These loadings do not constitute a significant portion of the total load on their respective city sewer systems or treatment plants.

It is estimated that raw organic wastes originating from domestic, municipal, and industrial sources within the Columbia Basin Irrigation Project area average approximately 850,000 population equivalents (PE) at the present time. Table VIII-1 shows a breakdown of the wastes produced. Wastes produced by industrial sources constitute about ninety percent of this amount.

TABLE VIII-1

WASTES PRODUCED WITHIN THE COLUMBIA BASIN IRRIGATION PROJECT

Source	Raw Waste PE/day*	Raw Waste Avg. PE/day
Domestic (unsewered)	31,400	31,400
Municipal (sewered)	43,600	43,600
Larson Air Force Base (domestic)	5,000	5,000
Industrial:		
Potato processing	172,000	143,400
Beet processing	756,000	630,000
Total	1,008,000	853,400

---

* PE per operating day for the industrial plants.

b. Municipal and Domestic

Out of the 25 cities and towns located within the project boundaries, 17 of these, having a total population of 2,400, are not served by collection systems. Septic tanks with subsurface disposal systems are the predominant means of sewage disposal in these towns. The rural population of about 31,400 also disposes of waste by means of septic tanks. Eight cities with a total population of 43,600 and Larson Air Force Base are served by collection systems and conventional waste treatment facilities (Table VIII-2).

Pasco discharges plant effluents to the Columbia River, and the City of Moses Lake discharges plant effluents to Moses Lake. The remaining six cities, which serve 17,100 people, utilize land disposal or no-overflow lagoons. Two of these cities, which serve 3,200 people, provide secondary treatment with chlorination. This reduces the PE applied to the land from these two cities to about 450. Three communities, serving 12,800 people, provide primary settling followed by lagoons. Two of these three use lagoon effluent for irrigation purposes, while the third, which serves 6,500 people, uses lagoons with no overflow. The remaining city providing treatment serves 1,100 people, and provides a no-overflow raw sewage lagoon for treatment.

c. Industrial

The seasonal operation of the food-processing plants causes variability in volumes and strengths of wastes. When the

TABLE VIII-2

COLUMBIA BASIN IRRIGATION PROJECT--MUNICIPAL WASTE INVENTORY, 1963

Area	Town	Pop. Served	Type Sew.Sys.	Avg. Daily Flow		Discharge to	Design Criteria			Treatment
				MGD	gpcd		MGD	GPCD	PE	
(1)	Ephrata	6,500	Separate	0.61	93	No overflow.	1.4	100	14,000	Prim.sed.fol.by 3 lagoons series.
(1)	George	(190)	None							
(1)	Larson AFB	5,000	Separate	0.47	94	Land appl. thru percolation beds.				Prim.sed.,chlor. facil. available.
(1)	Moses Lake	10,500	Separate	0.86	80	Moses Lake.	1.8	120	15,000	TF plus chlor.
(1)	Quincy	3,300	Separate			Irrigate corn and wheat.	4.8	120	4,000	Prim.sed.fol.by 3 lagoons.
(1)	Soap Lake	2,300	Separate	0.16	70	Subsurface.	0.38	100	3,800	TF plus chlor.
(1)	Westlake	(500)	None							
(2)	Wheeler	(200)	None							
(2)	Wilson Creek	(270)	None							
(3)	Othello	3,000	Separate			Irrigate pastureland.	0.5	100	5,000	Prim.sed.fol.by 2 lagoons series.
(3)	Royal City	(400)	None							
(3)	Warden	1,100	Separate			No overflow.			1,800	Lagoons.
(4)	Mattawa	(150)	None							
(5)	Connell	900	Separate			Esquatzel Coul.	0.1	100	1,000	Trick.fil.plant (TF) w/chlor.
(5)	Eltopia	(150)	None							
(5)	Hatton	(75)	None							
(5)	Mesa	(290)	None							
(5)	Pasco	16,000	Combined	1.24	78	Columbia River.	3.6	180	20,000	Prim.sed.+chlor.

plants are in peak operation (June through March), total waste production averages about 968,000 population equivalents per day. Due to a lack of industrial waste data, the PE shown for potato and beet processing in this report is based only on typical values (X-5).

Table VIII-3 summarizes the industrial waste disposal methods employed in the project area. Lagoons or primary settling followed by land application of the effluent by various methods of irrigation are the chief methods of industrial waste disposal. In a few instances, disposal is by no-overflow lagoons.

A localized odor problem associated with a starch plant waste has been reported. The lagooned portion of this waste also had high foaming characteristics which prevented pumping to the irrigation system.

Waste flow from a sugar-processing plant enters the project irrigation wasteway when weather permits and is held in no-overflow lagoons during other times. The amount of percolation into the soil from the no-overflow lagoons has not been determined. The BOD of the ground-water flow entering the wasteway remained relatively low (5-10 mg/1).

d. Irrigation Return Flows

A portion of the water applied to land for irrigation purposes drains from the irrigated land as surface or subsurface drainage. Of the many factors acting to change the quality of the water as it passes over the land, the principal ones are leaching,

TABLE VIII-3

COLUMBIA BASIN IRRIGATION PROJECT INDUSTRIAL WASTE INVENTORY, 1963

Industry	Location	PE per Operating Day	Average Annual PE	Waste Water Flow (MGD)	Disposal Method
Beet	Moses Lake	756,000	630,000	2.9	Primary settling followed by sprinkler irrigation; no overflow lagoons used during severely cold weather.
Potato	Moses Lake	160,000	133,000	0.7	No-overflow lagoons for a portion of the wastes and ridge and furrow irrigation for the remainder.
Potato	Warden	32,000	26,700	0.5	Lagoons, no overflow.
Potato	Othello	20,000	16,700	1.2	Storage ponds followed by sprinkler irrigation.

evaporation, transpiration, ion exchange, erosion, heat transfer, precipitation of salts and colloids, and biochemical alteration of water and soil constituents (X-7). The portion of the return flow from the project which eventually reaches the Columbia River as subsurface drainage is variable and has not as yet reached equilibrium. The anticipated effects of the proposed East High system on the ground-water table will extend this condition some time into the future.

Shortly after initial operation of the project, it was found that about 12 percent of the water diverted to the area returned to Potholes Reservoir. The increase since that time has been slightly less than three percent per year and is expected to eventually reach a nearly constant percentage.

Data supplied by the U. S. Bureau of Reclamation which show conditions existing in 1962 indicate that the annual return flow, surface and subsurface, entering Potholes Reservoir for that year was about 400,000 acre-feet, or approximately 41 percent of the water diverted to lands at that time.

2. Future

a. Domestic, Municipal, and Industrial

Future waste production is projected on the same basis as was used to estimate future domestic, municipal, and industrial water needs. No significantly different types of wastes other than those now present are anticipated. Projections indicate that sewage and industrial waste production with full project development will be about 4,150,000 PE by 1985 and about 6,250,000 PE by the year 2010 (Table VIII-4). Nearly 96 percent of this waste will be associated with industrial processing.

TABLE VIII-4

FUTURE WASTE PRODUCTION
FULL DEVELOPMENT OF COLUMBIA BASIN IRRIGATION PROJECT
Population Equivalents

Source	1985	2010
Domestic (unsewered)	46,000	53,000
Municipal (sewered)*	117,000	206,000
Industrial	4,000,000	6,000,000

* Includes domestic wastes of Larson Air Force.

In the absence of the East High system, the total PE of the raw wastes would be about one-third less than with this development, or a total PE of 2,700,000 by 1985 and 4,100,000 by 2010.

b. Irrigation Return Flow

Irrigation return flows to the Columbia River will continue to increase as more acres are irrigated and may be expected to reach 1,500,000 to 2,500,000 acre-feet per year (35 to 55 percent of the ultimate diversions) with the fully developed project.

C. Present and Future Water Quality

1. Present

a. Surface Water Quality

The water imported to the area from the Columbia River is of adequate quality to serve all needs in the region. The dissolved solids are in the range of 120-140 ppm when entering the project area (West Canal and East Low Canal, Appendix B, Table B-1). Even after storage, passage, and mixing with surface flows and irrigation return flows, the waters delivered to the lower part of the project from Potholes Reservoir and Scootenay Reservoir are generally less than 300 ppm (Appendix B, Table B-1).

About 55 percent of the inflows to Moses Lake are from Upper Crab Creek, the historic stream in the area, and Rocky Ford Creek, which is spring-fed. The remainder is from ground-water inflow. Concentrations of dissolved solids in Moses Lake range from about 250 to 450 mg/l. Algal blooms and turbidity caused by carp activity make the lake less attractive for recreation and sport fishing. The algae production is thought to be the result of abundant phosphate input to the lake (X-21). About 41 percent of the phosphate is from the Moses Lake sewage treatment plant, and about 39 percent is from springs which feed Rocky Ford Creek. The remaining 20 percent may be contributed by such sources as cattle feed lots adjacent to the inflowing streams, a fish hatchery on Rocky Ford Creek, numerous migratory waterfowl, and ground-water inflow. Analysis of samples collected at various points in the lake is shown in Appendix B, Table B-1. Most Probable Numbers (MPN) of coliform organisms (X-9, 17) have remained less than 100 per 100 ml, which indicate no health hazard for recreation use. Algae, however, exert a significant oxygen demand on the lake waters. Samples collected about two feet off the bottom at a depth of about 30 feet during the summer of 1963 showed dissolved oxygen (DO) ranging from 2.7 to 7.3 mg/l. Algal or phytoplankton counts at the time of DO sampling were as high as 27,000 in samples collected 18 inches below the surface. Large trout have been caught in the lake and apparently grow quite rapidly, however.

Crab Creek, below Potholes Reservoir, is considered by fisheries agencies to be potentially suited for anadromous fish. The chemical quality does not appear to be limiting for the rearing of fish (X-16). Dissolved solids do not exceed 700 ppm, and the dissolved oxygen is at a relatively high level (over 6.0 mg/l). Bacteriological samples collected from Crab Creek (near Smyrna, Appendix B, Table B-1) showed coliform organisms (MPN) as high as 46,000 per 100 ml. It is believed that these bacteria are contributed by cattle pastured on lands through which the stream flows. The temperature range in Crab Creek is from 70 to 77° F during the summer months.

Data on Columbia River water quality above and below the project on the western periphery are shown in Appendix B, Table

B-2. These data show quality to be similar in character throughout this reach.

Traces of chlorinated hydrocarbon insecticides up to 116 parts per trillion (.000116 mg/l) have been found. Herbicide 2,4-D up to 1,370 parts per trillion (.001370 mg/l) in some of the surface-water return flows in the area, and traces in the bottom muds of Moses Lake and Crab Creek have also been reported (Appendix B, Tables B-4, B-5, and B-6). The sampling in the summer of 1964 showed that the traces did not persist and that these occurred only intermittently.

b. Ground-Water Quality

The mineral quality of ground water in the region closely resembles that of surface water. An examination of 72 wells (Appendix B, Tables B-3 and B-6) in the study area revealed that the dissolved solids or electrical conductivity of ground water resembled that of Crab Creek, Rocky Ford Creek, and Scootenay Reservoir (Appendix B, Table B-1).

The electrical conductivity (EC) of well water ranged from about 200 to 2,000 (approximately 140 to 1,400 mg/l total dissolved solids). Thirteen samples exceeded an EC of 700 (about 500 mg/l), as shown in Table VIII-5. One difference between the surface and ground waters was the concentration of nitrate nitrogen. The surface waters generally contained only a fraction of a mg/l

TABLE VIII-5

WELLS WITH DISSOLVED SOLIDS CONCENTRATIONS EXCEEDING 500 MG/L (CONDUCTIVITY OVER 700) OR WELLS WITH NITRATE-NITROGEN CONCENTRATIONS EXCEEDING 10 MG/L

Well Location	Drainage Area From Map Fig. 3	Depth in Feet	EC x 10^6 @ 25°C	Nitrate Nitrogen mg/l	
18/25-4A	1	126	750	15	
20/25-3R1	1	168	750	8	
18/29-17P1	2	342	680	14	
18/30-16R1	2	185	700	14	
19/31-22D1	2	25	1,400	14	East High Canal Service Area
20/30-10B1	2	145	400	10	" " " " "
21/28-23D	2	150	780	3	
15/28-24L1	4	398	1,100	2	
11/30-11C1	5	614	1,850	11	
14/30-8G1	5	371	1,000	8	
13/29-25	5	83	2,000	115	
13/30-30	5	93	1,300	42	
12/30-19	5	128	1,100	178	
13/30-29A1	5	540	800	11	
12/29-22	5	80	750	30	

(Appendix B, Table B-1). Some ground waters (Appendix B, Table B-3) contained concentrations of nitrate nitrogen greater than the limits (10 mg/1 as nitrogen, or 45 mg/1 nitrate) recommended in the Public Health Service Drinking Water Standards (1962).

There were nine wells within the project area with nitrate-nitrogen concentrations greater than 10 mg/1, six of which were at depths of less than 200 feet (Table VIII-5). There were 12 wells within the project area with nitrate-nitrogen concentrations from 2 to 10 mg/1, five of which were less than 200 feet deep and seven of which were at greater depths. Outside the project area where no irrigation water has yet been applied, two wells less than 200 feet deep had nitrate-nitrogen concentrations greater than 10 mg/1, and three deeper wells had concentrations from 2 to 5 mg/1.

Data show that before irrigation development the presence of nitrate-nitrogen in the well waters was quite widespread and occurred in the ground waters both within and outside the project area in varying quantities. Since the application of irrigation waters, some of the concentrations have decreased while others have increased. One infant mortality and several illnesses of methemoglobinemia have occurred as a result of high nitrates.

In the summer of 1964 bacteriological examinations and ammonia nitrogen determinations were made on six selected well supplies. Two wells showed coliform bacteria, one showed fecal coliform, and four of the wells had high background non-coliform bacteria counts up to 2,400/100 ml. These results are not conclusive as the condition of the well installation and casing was not known, but there is indication that rapid transit from the surface to the ground water occurred at these locations.

Traces of insecticides and herbicides were found in well waters in 1961 and 1962 by Washington State University (Appendix B, Tables B-4 and B-5). These traces were in the order of 0.2 parts per trillion (.0000002 mg/1). A series of samples analyzed by the Public Health Service during 1964 (Appendix B, Table B-6) showed traces of insecticides up to 150 parts per trillion. These traces did not persist in subsequent samplings. Traces of herbicides were also found in two well samples but were not detected in subsequent samples. These results also confirm a ready access of shallow water to the well supply.

All of the wells in Appendix B, Tables B-1 and B-6, were plotted on a map. The sample wells are believed to be fairly representative of the 6,000-7,000 wells in the region (X-1). From this plotting it was found that, in addition to the general occurrence of high nitrate-nitrogen concentrations at shallow depths, most of the problem wells occurred in two general localities--in the Moses Lake-Potholes Reservoir locale in drainage area 2 (see map, Figure 3) and in the Mesa-Eltopia locale in drainage area 5. The present ground-water quality as it is known and the projected future quality under conditions of future development are discussed below by these ground-water divisions. Other studies (X-12, 17) show that the water is fairly hard (average 240 mg/l as calcium carbonate) and may present some economic problems. The importance of this problem, however, is not as significant as the toxicological effects associated with high nitrates.

2. Future

a. Surface Water

Surface water quality, with the completion of the authorized development and with the addition of East High Canal development, can be expected to be very similar to that existing at the present time. This is mainly due to the type of soils being irrigated. It is projected that the algal growth in Moses Lake will be further aggravated by nutrient-rich ground waters from additional irrigation development of East High Canal. Other impoundments may be similarly affected. This is discussed further in the next section on ground-water quality.

b. Ground Water

Area 1

This area in the northwest section of the project is the most completely developed (over 80 percent). All eleven wells studied in this area appear to be decreasing in nitrate-nitrogen concentration. Four wells outside the area on the west periphery are not decreasing. The nitrate-nitrogen concentration is less than the 10 mg/l limit of the Public Health Service Drinking Water Standards (1962) except for one shallow well. Another shallow well showed a trace of DDT in June 1964. The future withdrawal of ground water from wells deeper than 200 feet should be of adequate quality for domestic supply. Shallower wells possibly will improve somewhat in the future.

Area 2

Of the 16 wells studied in this area, one shallow well and one well 342 feet deep showed nitrate-nitrogen concentrations over 10 mg/l. Two shallow wells in the now undeveloped East High Canal service area have high nitrate-nitrogen concentrations. One shallow well showed a trace of pesticide in 1964. With the development of additional lands in this area, the shallow ground water is not expected to improve. With additional irrigation water in this area, the existing nitrates could be moved and could aggravate algae problems in Moses Lake and possibly Potholes Reservoir. It is possible also that additional nitrates might occur at greater depths.

Areas 3 and 4

One well in these areas showed a high concentration of dissolved solids. The nitrate content, however, was below the critical limit. The wells in the area yet to be developed are relatively low in nitrate. It is believed that nitrate problems will not develop generally in these areas with further project development.

Area 5

Ground-water quality in this area appears to be the most serious. Seven of the 15 wells studied showed high dissolved solids concentrations and nitrate-nitrogen concentrations up to 200 mg/1. The shallow wells showed the highest concentrations of dissolved solids and nitrate nitrogen as shown in Table VIII-5. Three of the wells showed traces of pesticides in the summer of 1964, and two of the same wells showed the presence of coliform organisms and had high bacterial plate counts. Two other wells showed bacterial counts. All evidence suggests ready access of surface water to the ground water supply. With irrigation of new lands in the Providence, Washtucna, and Esquatzel Coulee areas, it is not known whether the shallow ground water quality could be expected to improve or worsen.

IX. WATER QUALITY CONTROL NEEDS AND BENEFITS

A. Water Quality Control Needs

1. Waste Treatment

The Washington State Pollution Control Commission has adopted regulations (X-20) regarding waste disposal methods for municipal wastes, household wastes, and industrial wastes. Continued compliance with these regulations (Appendix C) should provide suitable control into the future. With this control, the major influence on water quality and sanitation within the project will continue to be irrigation system seepage and return flows.

Careful handling and control of wastes are and will continue to be essential for the protection of surface and ground-water quality in the project area. The quality of Roosevelt Lake water which is used for irrigation will continue to be degraded, as it flows over or through the land to which it is applied. This degradation is inherent in the nature of the project and may be at least partially controlled by land management practices, including efficient use of water and chemicals. Municipal and industrial waste pollution, however, can and must be controlled by a high level of treatment.

Current disposal techniques, which rely heavily upon ultimate land disposal, have proven adequate to date. With full development of the irrigation system and continued rise in the ground-water table, the examination of ground-water quality will become more and more important. The lack of streams suitable for waste disposal throughout most of the project, however, makes it necessary to continue to dispose of wastes to the land, to reservoirs or lakes, or to irrigation drains.

Perennial streams which will be created by full project development may prove advantageous to current waste disposal methods. The City of Connell, located on Esquatzel Coulee, is the only town presently discharging wastes to a dry coulee. Secondary waste treatment followed by chlorination should produce an effluent suitable for discharge to the stream which will be formed in this coulee.

2. Water Management

There are several specific water quality control problems in the area which require special mention. These are:

a. Turbidity and algae in Moses Lake.

b. Domestic ground-water supplies containing high nitrate nitrogen, dissolved solids, and traces of pesticides.

The need for improving Moses Lake relates mainly to recreation, fishery, and aesthetic values. The factors associated with algae control are not well defined but are known to involve warm temperature, abundant sunshine, and plentiful nutrients. Several methods are suggested by Sylvester (X-21) and could involve one or a combination of the following methods:

a. Dilution by routing high quality Columbia River water through the lake enroute to its use for irrigation.

b. Control of the input nutrient level.

c. Use of chemical control for all or part of the lake.

The dilution method has several disadvantages, as it might demand additional canals or pumps to move the water back to its destination for irrigation and could be quite costly. It also might translocate the problem and increase the aquatic growth problem in other project impoundments or canals. The project is now expending about $390,000 annually on the aquatic growth control program.

Nutrient control holds promise in part. Tertiary treatment or discontinuance of effluent disposal to the lake from the City of Moses Lake could accomplish removal of about 40 percent of the present phosphate (about 169,000 lbs. annually). Increased populations in the Moses Lake area, as projected in Chapter V, should be recognized in this regard. Removal of phosphates by treatment of Rocky Ford Creek would provide nearly another 40 percent removal. This, however, would be difficult and expensive because of the large volume of water. There appears to be no way of controlling phosphate contributed by groundwater inflow. It may be expected also that additional quantities of phosphate will be contributed with development of irrigation under East High Canal.

Harvesting carp from the lake would remove a small portion of the phosphates (4 lbs. PO_4 per ton), but would improve the appearance of the lake by reducing the turbidity. Carp cause turbidity by destroying the vegetation needed to hold down turbidity. However, reduction of the turbidity may result in greater light penetration and induce more algal growth.

3. Chemical Treatment

Algicide treatment of lakes and standing water bodies is possible but expensive, and is not compatible with a fishery. Careful algicide treatment of portions or arms of lakes that are used for swimming, however, might be accomplished without detriment to the fishery in other portions of the lakes.

4. Source Development Alternatives

The quality of ground water for domestic purposes is the greatest problem needing attention. It appears that in the Mesa-Eltopia area deeper wells would provide water of suitable quality with some measure of certainty. High nitrate waters, however, occur at greater depths, especially in the Moses Lake-Potholes Reservoir area. For individual domestic use, small deionizing units could be used to remove the minerals, including nitrates. Charcoal or carbon filters could assist in removing pesticides. Another possibility would be to truck water to the area from established suitable sources.

Each of the two major ground-water problem areas (Mesa-Eltopia and Moses Lake-Potholes Reservoir areas) is within a radius of six to ten miles. The installation of community distribution systems and treatment plants which would utilize the high-quality Columbia River water from the project in exchange for ground water might be the answer to the problem. In addition to benefiting domestic supplies by this exchange, the use of high-nitrate ground water (30-150 mg/1) for irrigation would benefit agriculture by providing a source of nitrogen. The amount of nitrogen that could be provided (80-400 pounds per acre-foot) would satisfy most of the requirement for crops if used at the proper time of the growing period.

5. Surveillance

A water quality surveillance program coordinating the efforts of all interested agencies should be initiated for the purpose of more fully describing existing water quality and identifying future changes in water quality. This program would relate quality measurements to present surface flows and those created by additional development. A ground-water sampling program should be designed in such a manner that, in conjunction with ground-water hydrologic data, an evaluation and interpretation of water quality changes could be made. The collection of chemical data should include not only major mineral constituents but also minor elements that might influence aquatic growths. Included also should be measurements of physical, biochemical, bacteriological, and pesticide quality as deemed necessary to evaluate the public health and aesthetic significance of water quality.

6. Vector Control

The irrigation seepage has created several standing bodies of surface water to date, and the use of the East High Canal will create even more. An evaluation of potential vector problems related to the irrigation project has been made by the Public Health Service, Communicable Disease Center, and Washington State Department of Health (see Appendix E). It is expected that development of the East High Canal will add to existing vector and disease problems in developed parts of the project. In order to minimize public health hazards, it is recommended that the principles and practices for prevention and elimination of mosquito sources associated with irrigation be carried out as outlined in Appendix E.

B. Water Quality Control Benefits

The development of irrigation in this formerly arid region has provided an abundant ground-water resource which previously did not exist. Some of the ground water has been found to be unsuitable for domestic use. Ways and means of improving these supplies should be given the utmost attention.

There is no feasible way of directly improving ground-water quality by project design or operation. Provisions for an exchange of high-quality surface water for high-nitrate ground water in some areas would benefit domestic users as well as agriculture.

If project water were passed through Moses Lake to improve the quality of the lake, benefits could be assigned to the project for water quality control. This would apply, however, only after nutrient control by other means had been accomplished and if the additional flow was still then required.

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APPENDIX A

HYDROLOGIC DATA

TABLE A-1

1962 COLUMBIA BASIN IRRIGATION PROJECT CANAL FLOWS

Location	Net Supply				Diversions		Waste		Apparent Loss	
	Annual		Max. 30-Days		Ann.	Max.30-	Ann.	Max.30-	Ann.	Max.30-
	Ac.-Ft.	cfs	Ac.-Ft.	cfs	cfs	da.cfs	cfs	da.cfs	cfs	da.cfs
Main Canal	1,753,500	2,420	395,000	6,650	2,030	5,900	136	175	249	555
West Canal (Total)	912,000	1,260	211,000	3,540	1,160	3,340	121	207	251	561
East Low Canal (Total)	789,400	1,090	173,800	2,920	870	2,530	76	86	143	258
Potholes East Canal (Total)	486,450	670	102,470	1,730	625	1,635	80	154	75	95
West Canal										
Bifurc. to Frenchman Tunnel	689,400	957	159,400	2,680	890	2,540	48	58	15	67
Royal Branch Canal	93,800	130	20,600	364	124	354	4	3	1.4	6.2
East Low Canal										
Bifurc. to Mile 37	295,100	406	64,600	1,090	336	975	23	0	49	121
Mile 37 to Mile 56	117,200	162	24,270	409	81	256	26	38	55	114
Mile 56 to End	377,200	520	84,890	1,430	454	1,350	27	53	40	23
Potholes Canal										
Head to Scootenay Headworks*	106,500	148	24,300	409	194	534	1.4	1.2	48	127
Wahluke Branch Canal	67,100	92	14,900	252	83	219	1.4	1.2	8	33
Scootenay Headworks to End	379,900	524	78,100	1,310	434	1,100	48	67	45	145

*Includes Wahluke Branch Canal

TABLE A-2

DISCHARGE OF CRAB CREEK 3 MILES UPSTREAM FROM MOUTH (MOSES LAKE), cfs
(USGS Gaging Station)

Water	Mean Discharge														
Year	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Average	Max.	Min.
1951	1.1	0.4	0.3	0.2	220	389	183	65	14	1.5	0.9	0.4	-----	1,590	0
1952	0.3	0.2	0.1	0	52	85	141	42	42	55	67	75	-----	195	0
1953	67	16	10	8	4	4	9	26	58	76	94	90	38	109	0
1954	66	24	13	10	9	7	12	29	42	63	80	78	36	95	2
1955	66	31	14	13	73	87	47	21	20	36	39	44	41	355	7
1956	34	24	19	351	193	1012	287	100	43	35	42	46	179	3090	10
1957	41	27	20	12	228	802	57	30	26	31	35	36	112	10400	8
1958	33	22	15	13	25	123	74	26	20	34	40	37	38	166	10
1959	32	23	17	779	285	482	96	39	18	25	40	47	157	5000	6
1960	32	20	14	10	422	51	43	22	17	32	43	41	62	1230	8
1961	29	24	16	12	268	124	90	37	20	32	37	38	104	534	9
1962	35	23	17	12	17	60	35	13	18	32	44	42	29	347	8
Mean*	44	23	16	122	152	275	75	34	28	40	49	50	76		

*1953-1962

TABLE A-3

DISCHARGE OF ROCKY FORD CREEK 5 MILES UPSTREAM FROM MOUTH (MOSES LAKE), cfs
(USGS Gaging Station)

Water Year	Mean Discharge														
	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Average	Max.	Min.
1951	92	83	75	69	67	67	83	98	101	99	94	91	85	108	64
1952	88	84	79	73	72	78	85	90	92	97	103	103	87	106	70
1953	106	104	94	84	79	85	99	99	96	94	94	90	94	109	77
1954	89	86	78	71	68	67	78	90	90	91	95	93	83	100	63
1955	91	83	78	78	73	76	90	95	97	105	102	101	89	109	71
1956	98	86	77	75	110	169	206	199	179	165	155	144	139	212	69
1957	138	129	117	104	95	100	122	129	125	118	114	107	117	142	88
1958	100	97	90	85	88	103	103	99	94	92	92	94	95	108	82
1959	93	85	80	75	89	117	144	138	122	112	108	103	106	148	72
1960	98	94	86	74	70	86	98	94	87	91	100	100	90	106	67
1961	96	90	86	77	68	84	103	104	100	96	94	93	91	124	66
1962	91	83	74	70	68	78	97	111	106	103	102	92	90	114	67
Mean	98	92	85	78	86	101	109	112	107	105	105	101	97		

TABLE A-4

DISCHARGE OF CRAB CREEK NEAR WARDEN (BELOW POTHOLES RESERVOIR), cfs
(USGS Gaging Station)

Water	Mean Discharge														
Year	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Average	Max.	Min.
1956	29.0	29.8	30.1	30.5	32.4	33.4	32.3	31.2	31.0	31.1	31.1	32.0	31.2	37	29
1957	32.6	33.0	33.0	31.3	32.0	33.0	32.7	31.0	29.5	28.6	29.2	31.2	31.4	35	28
1958	30.0	30.9	29.0	29.3	28.9	29.8	33.2	19.2	24.2	25.8	22.1	22.3	27.1	392	3.6
1959	23.6	25.2	28.7	29.6	32.7	28.5	24.4	25.4	25.5	21.5	20.2	22.4	25.6	174	11.5
1960	26.2	31.6	35.8	19.8	31.3	27.7	28.9	25.9	20.3	20.9	23.8	25.0	26.4	372	10
1961	25.8	26.5	26.1	27.0	28.3	27.8	26.0	25.7	24.2	22.6	22.8	20.7	25.3	35	18.5
1962	20.7	21.9	23.1	24.7	25.6	24.9	24.2	23.3	21.6	22.3	20.5	17.4	22.5	29	16
Mean	26.8	28.0	29.4	27.4	30.2	29.3	28.8	26.0	25.3	24.7	24.2	24.5	27.1		

Note: Flow controlled by Potholes Reservoir after October 1952 and no flow was released until October 1956. Flow was zero from October 1952 to October 1955.

1958 - Partial failure of dam resulted in high maximum flow.
1959 - " " " " " " " " "
1960 - " " " " " " " " "

TABLE A-5

DISCHARGE OF CRAB CREEK 4.5 MILES UPSTREAM FROM MOUTH (@ BEVERLY), cfs
(USGS Gaging Station)

Water	Mean Discharge														
Year	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Average	Max.	Min.
1959	--	--	--	--	--	62.7	51.6	52.9	48.4	32.6	48.9	71.6	--	105	16
1960	79.0	66.0	58.7	63.6	88.7	55.0	52.3	50.8	62.3	51.2	56.7	68.0	62.6	177	15
1961	64.4	64.8	58.4	61.9	81.8	67.2	57.2	62.0	65.4	47.5	50.9	66.9	62.2	101	30
1962	73.2	67.7	70.6	65.9	71.8	61.1	62.2	83.8	70.2	53.5	60.6	72.6	67.7	102	12
Mean	72.2	66.2	62.7	63.8	80.8	61.5	55.6	62.3	61.5	46.1	54.3	69.9	64.2		

TABLE B-1

Surface Water Quality Summary

Columbia Basin Irrigation Project

Sampling Station	Date	DO mg/l	% DO Sat.	Concentration (mg/l)																						Coliform MPN/100 ml.	Conductivity umhos @ 25°C.	pH	
				NH_3-N	NO_3-N	Org. N	PO_4	Soluble Phosphate	Total Alkalin.	HCO_3	CO_3	Tot.Hard. as $CaCO_3$	SO_4	Total Solids	Dissolved Solids	Fe	Ca	Mg	Na	K	Cl	F	SiO_2	Color	Turbidity				
Crab Creek 2 mi. above Moses Lake	5/54- 9/54 (8)	12	12	12					12	12	12	12	12	12		7	7	7	7	7				12	12		12	12	No. of obser.
		9.4	99	Tr					152	126	1	91	28	270		.1	22	1	24	4.2				12	6		365	8.0	Minimum value
		10.0	107	.02					160	142	16	130	43	315		.1	22	2	28	4.2				17	25		394	8.4	Mean value
		11.1	120	.04					170	162	44	146	61	411		.1	23	2	33	4.2				30	90		452	8.9	Maximum value
	4/63- 10/63 (9)			9	11	10	8	11	10		9	3	2			2	10	8	3	3	3				11	10	10	10	No. of obser.
				0	.04	0	.2	0	180		0	173	34			.25	28	12	42.5	14	10.5				4	29	234	8.1	Minimum value
				.05	.35	.13	.71	.17	207		6	197	35			.27	32	19	55	14	12				23	1,040	445	8.3	Mean value
				.15	.88	.23	1.4	.33	230		20	244	36			.28	49	28	57	14	14.5				121	4,600	670	8.6	Maximum value
Crab Creek Near Smyrna	6/54- 9/54 (8)	9	9	9					9	9	9	9	9	9										9	9		9	9	No. of obser.
		8.3	96	0					322	266	36	157	107	612										23	27		824	8.5	Minimum value
		8.8	101	.01					330	284	46	170	176	685										39	37		850	8.6	Mean value
		9.4	112	.03					338	293	56	180	290	804										52	60		885	8.7	Maximum value
	11/59- 3/60 (10)	6			13			13		13	13	13	13		13		13	13	13	13	13	13	13	13		6	13	13	No. of obser.
		9.6			.13			0		349	0	200	120		577		40	22	115	13	40	1.0	28	5		91	895	7.8	Minimum value
		11.7			.22			.27		388	0.4	214	127		610		43	26	130	14	45	1.1	31	12		2,320	960	8.1	Mean value
		13.2			.33			.64		447	3	239	135		677		45	31	156	17	50	1.3	36	20		24,000	1,070	8.3	Maximum value
	4/60- 10/60 (10)	6			12		12			12	13	12	12		12		12	12	12	12	12	12	12	12		6	12	13	No. of obser.
		6.4			.13		0			300	0	178	98		463		34	22	95	12	37	0.6	17	5		750	780	7.9	Minimum value
		9.8			.16		.13			350	0	206	126		575		41	25	120	15	44	0.9	25	19		14,500	900	8.1	Mean value
		12.4			.30		.54			415	0	219	141		677		45	29	150	18	55	1.1	29	45		46,000	1,030	8.2	Maximum value
Rocky Ford Cr. 5 mi. above Moses Lake	5/54- 9/54 (8)	11	11	11					11	11	11	11	11	11		7	7	7	7	7				11	11		11	11	No. of obser.
		10.5	101	0					145	145	0	130	22	252		0	23	1.0	19	5.4				2	3		361	7.6	Minimum value
		11.7	115	.03					163	163	0	135	25	264		.10	25	1.2	22	5.5				7	4		367	7.9	Mean value
		13.9	142	.06					177	177	0	148	27	289		.20	26	1.5	24	5.6				10	6		381	8.0	Maximum value
	4/63- 10/63 (9)			10	11	10	7	11	10		9	3	2			2	10	8	3	3	3				11	9	10	10	No. of obser.
				0	.02	0	.24	.30	144		0	136	21			.22	20	8	32	12	6				2	91	213	6.7	Minimum value
				.08	.66	.08	.44	.42	155		0	138	23			.28	29	15	39	13	8				12	450	333	7.9	Mean value
				.20	1.61	.21	.52	.57	166		0	142	26			.35	39	20	50	15	11				33	1,100	473	8.7	Maximum value
Moses Lake Main Horn, offshore from State park	5-8/57 6-10/58 (11)				4					4	4		4				4	4	4	4	4						4	4	No. of obser.
					0					195	0		33				20	14	30	7.8	10						331	7.2	Minimum value
					0.2					202	0		38				27	16	36	10.2	12						404	7.8	Mean value
					0.8					211	0		43				30	18	40	12.5	15						447	8.3	Maximum value
	May-Oct. 1960-62 (11)				9					9	9		9				9	9	9	9	9						9	9	No. of obser.
					0					121	0		33				14	14	33	7.8	11						352	7.3	Minimum value
					.08					194	3		39				26	17	36	8.9	13						415	8.1	Mean value
					0.5					220	17		45				31	18	40	11.3	14						446	9.0	Maximum value

TABLE B-1 (Continued)

Sampling Station	Date	DO mg/l	% DO Sat.	C o n c e n t r a t i o n (mg/l)																					Turbidity	Coliform MPN/100 ml.	Conductivity umhos @ 25oC	pH	
				NH_3-N	NO_3-N	Org. N	PO_4	Soluble Phosphate	Total Alkalin.	HCO_3	CO_3	Tot. Hard. as $CaCO_3$	SO_4	Total Solids	Dissolved Solids	Fe	Ca	Mg	Na	K	Cl	F	SiO_2	Color					
Moses Lake	5/63-	9	9	8	10	9	8	10	9		11	3	5			2	12	11	5	5	5				10	9	12	12	No. of obser.
Main Horn, off-	10/63	7.0	62	0	0	0	.3	.07	140		0	128	24			0.5	14	11	33	8.6	11				14	0	288	7.6	Minimum value
shore from St.	(9,11)	8.2	93	.08	.07	.15	1.1	.31	161		17	138	31			0.8	26	16	46	12	12				26	32	390	8.1	Mean value
park (Cont.)		11.1	131	.24	.30	.38	3.7	1.64	184		40	150	38			1.2	33	19	63	14	14				110	75	576	8.8	Maximum value
Pelican Horn,	5/63-	7	7	10	10	10	8	10	9		7	2	2			2	9	8	2	2	2				10	8	9	9	No. of obser.
1.5 mile down-	10/63	8.6	94	0	0	0	.25	.04	144		0	127	31			.01	19	10	63	11	16				0	0	293	7.7	Minimum value
stream from	(9)	10.3	116	.09	.11	.21	.75	.12	174		36	144	38			.18	25	18	64	12	19				20	11	400	8.8	Mean value
Moses Lake STP		13.1	154	.70	.78	.40	1.5	.22	234		88	152	45			.35	52	24	65	13	22				56	43	479	9.4	Maximum value
Main Horn,	5/63-	8	8	9	10	8	7	10	9		7	2	2			2	9	8	2	2	2				9	8	9	9	No. of obser.
opposite	10/63	5.7	64	0	0	0	.25	.06	144		0	122	23			.47	14	9	39	13	11.5				7	0	249	7.6	Minimum value
Larson AFB	(9)	7.6	86	.18	.04	.15	1.0	.23	170		18	130	24			.48	22	15	51	14	13				25	11	352	8.4	Mean value
beach		9.5	111	.53	.12	.29	2.5	1.0	262		48	138	25			.48	27	20	63	14	14				125	75	420	9.1	Maximum value
Moses Lake	5/63-			5	9	10	8	10	9		8	2	2			2	9	8	2	2	2				8	13	8	9	No. of obser.
STP Effluent	10/63			1.3	.04	.3	17	2.8	168		0	127	48			.32	15	10	60	14	64				4	150	586	7.2	Minimum value
	(9)			8.5	.8	.8	44	16	215		2	131	53			.32	21	16	95	16	71				19	2,260	880	7.8	Mean value
				17.8	1.7	1.6	58	22	264		18	134	59			.32	28	18	130	19	79				33	11,000	1,200	9.3	Maximum value
Moses Lake -	5/63-			8	9	8	8	8												1					9	7	8	8	No. of obser.
Tributary	10/63			0	0	0	.30	.03												15					0	4	336	7.3	Minimum value
Ground Seep	(9)			.09	3.1	.08	.57	.14												15					7	20	540	7.8	Mean value
nr. Goat Is.				.47	7.6	.23	1.0	.38												15					29	43	726	8.6	Maximum value
Scootenay Lake	7/58-				2					2	2		2				2	2	2	2	2						2	2	No. of obser.
	10/58				0					198	0		161				34	32	85	13	50						780	7.8	Minimum value
	(11)				0					212	3		168				36	32	86	15	50						798	8.0	Mean value
					0					226	6		175				39	32	87	17	50						816	8.3	Maximum value
Ringold Springs	4/60-				9				7			10							7		7						8		No. of obser.
	7/62				1				190			230							75		20						800		Minimum value
	(12)				2				195			300							85		45						950		Mean value
					5				200			450							100		75						1,250		Maximum value
	10-18-62				1					1	1		1				1	1	1	1	1						1	1	No. of obser.
	(11)				3.3					258	0		264				75	45	78	9.9	58						1,030	7.8	Mean value
West Canal at	5/63-				3					3	3		3				3	3	3	3	3						3	3	No. of obser.
Winchester	10/63				0					79	0		13				21	5	7	1.1	1						168	7.5	Minimum value
Wasteway	(11)				0					86	0		15				21	6	8	1.5	3						172	7.8	Mean value
					0					88	0		17				22	6	12	1.6	3						186	8.0	Maximum value
West Canal at	5/63-				3					3	3		3				3	3	3	3	3						3	3	No. of obser.
Frenchman Hills	10/63				0					85	0		16				21	5	7	1.1	2						162	7.6	Minimum value
Wasteway	(11)				0					87	0		17				21	5	10	1.7	3						175	7.8	Mean value
					0					92	0		18				23	6	12	2.3	4						190	7.9	Maximum value

TABLE B-1 (Continued)

				Concentration (mg/l)																									
Sampling Station	Date	DO mg/l	% DO Sat.	NH_3-N	NO_3-N	Org. N	PO_4	Soluble Phosphate	Total Alkalin.	HCO_3	CO_3	Tot.Hard. as $CaCO_3$	SO_4	Total Solids	Dissolved Solids	Fe	Ca	Mg	Na	K	Cl	F	SiO_2	Color	Turbidity	Coliform MPN/100 ml.	Conductivity umhos@ 25°C	pH	.
East Low Canal at Wheeler	5/63-10/63 (9)			8	10	9	8	10	9		8	2	2			2	9	7	3	2	2				10	9	9	9	No. of obser.
				0	0	0	0	0	60		0	76	12			.03	13	4	6	4	0				1	0	95	7.0	Minimum value
				.04	.02	.05	.45	.07	66		0	76	35			.04	20	7	9	6	1				6	20	140	7.8	Mean value
				.12	.06	.15	1.7	.44	74		0	77	58			.05	22	22	14	7	2				18	43	171	8.3	Maximum value
Potholes East Canal at Headworks	June-Sept. 1954-55 (8)	19	19	19					19	19	19	19	19	19		13	13	13	13					19	19		19	19	No. of obser.
		8.5	94	.05					132	115	8	106	20	177		0.1	30	0.5	16					10	5		287	8.2	Minimum value
		8.8	96	.17					145	129	16	112	21	192		0.2	38	3.1	20					11	10		313	8.4	Mean value
		9.2	101	.41					151	140	18	120	23	201		0.3	56	7.4	22					12	17		331	8.6	Maximum value
	5/60-10/62 (11)				9					9	9						9										9	9	No. of obser.
					0					156	0		47				20	16	30	6.2	19						389	7.8	Minimum value
					.15					171	0.1		55				26	21	37	7.7	21						425	8.1	Mean value
					0.5					193	1.2		63				36	22	41	9.4	24						470	8.5	Maximum value
	5/63-10/63 (11)				3					3	3		3				3	3	3	3	3						3	3	No. of obser.
					.13					176	0		62				27	18	38	7.0	17						447	7.7	Minimum value
					.13					183	0		65				31	19	39	7.7	21						460	7.9	Mean value
					.13					191	0		70				36	20	39	8.6	24						480	8.1	Maximum value
Potholes East Canal, Mile 26.6 (above Scootenay Reservoir)	7/54-9/54 (8)	9	9	9					9	9	9	9	9	9										9	9		9	9	No. of obser.
		9.6	102	0					143	125	3	105	24	200										10	10		316	8.4	Minimum value
		9.7	105	0					159	145	14	111	25	208										13	15		340	8.4	Mean value
		9.8	108	0					175	155	21	120	25	218										15	18		374	8.5	Maximum value
	5/57-10/58 (11)				4					4	4		4				4	4	4	4	4						4	4	No. of obser.
					0					162	0		29				22	13	29	7.8	11						332	7.7	Minimum value
					0					171	0		32				25	14	30	9	13						359	8.0	Mean value
					0					183	0		34				28	14	33	10	16						390	8.2	Maximum value
	5/60-10/62 (11)				9					9	9		9				9	9	9	9	9						9	9	No. of obser.
					0					135	0		42				20	14	28	5.5	18						366	7.5	Minimum value
					.15					155	2		49				22	17	32	6.8	19						395	8.1	Mean value
					.75					179	11		59				33	23	35	7.8	23						432	8.5	Maximum value
	5/63-10/63 (11)				3					3	3		3				3	3	3	3	3						3	3	No. of obser.
					.13					163	0		57				28	17	33	6.6	18						409	7.7	Minimum value
					.13					172	0		60				30	19	36	7.7	21						429	7.9	Mean value
					.13					183	0		65				34	20	37	8.7	23						462	7.7	Maximum value
Potholes East Canal Mi. 38.0 (below Scootenay Reservoir)	5/60-10/62 (11)				9					9	9		9				9	9	9	9	9						9	9	No. of obser.
					0					151	0		37				23	14	25	5.5	16						353		Minimum value
					.10					160	1		46				26	15	30	6.7	18						384		Mean value
					0.4					180	6		54				33	17	34	7.4	21						418		Maximum value

TABLE B-1 (Continued)

Sampling Station	Date	DO mg/1	% DO Sat.	Concentration (mg/1) NH$_3$-N	NO$_3$-N	Org. N	PO$_4$	Soluble Phosphate	Total Alkalin.	HCO$_3$	CO$_3$	Tot.Hard. as CaCO$_3$	SO$_4$	Total Solids	Dissolved Solids	Fe	Ca	Mg	Na	K	Cl	F	SiO$_2$	Color	Turbidity	Coliform MPN/100 ml.	Conductivity umhos @ 25°C	pH	
Potholes East Canal Mi. 38.0 (Continued)	5/57-10/58 (11)				4					4	4		4				4	4	4	4	4						4	4	No. of obser.
					0					158	0		28				22	13	27	7.0	11						327	7.7	Minimum value
					0					163	0		30				24	13	28	8.3	12						345	8.0	Mean value
					0					176	0		33				26	14	29	9.8	14						363	8.2	Maximum value
	5/63-10/63 (11)				3					3	3		3				3	3	3	3	3						3	3	No. of obser.
					0					159	0		56				26	16	33	6.2	20						407	7.7	Minimum value
					.13					167	0		59				29	18	36	7.3	20						424	8.1	Mean value
					.25					180	0		62				32	19	43	8.6	20						447	8.5	Maximum value
Potholes East Canal Mi. 65.8	June-Sept. 1954-55 (8)	19	19	19					19	19	19	19	19	19		19	19	19	19	19				19	19		19		No. of obser.
		9.1	97	0.1					112	106	6	102	14	202		0	25	0.4	17	3.0				6	7		234		Minimum value
		9.3	101	0.4					138	125	14	109	21	207		.14	30	2.3	24	5.9				9	16		296		Mean value
		9.4	106	0.9					156	138	18	115	24	211		0.4	34	4.2	34	8.3				12	30		321		Maximum value
	5/57-10/58 (11)				4						4		4				4	4	4	4	4	4					4	4	No. of obser.
					0						0		29				21	12	27	7.1	139	10					337	7.8	Minimum value
					0						2.6		31				24	13	28	8.0	154	12					343	8.1	Mean value
					0						10.5		34				26	14	29	8.6	171	13					353	8.5	Maximum value
	5/60-10/62 (11)				9					9	9		9				9	9	9	9	9						9	9	No. of obser.
					0					136	0		37				23	13	26	5.5	15						355	7.6	Minimum value
					.04					159	1		46				26	15	32	6.5	18						386	8.1	Mean value
					.13					174	6		55				29	18	38	7.1	21						410	8.7	Maximum value
	5/63-10/63 (11)				3					3	3		3				3	3	3	3	3						3	3	No. of obser.
					0					162	0		58				26	17	34	5.5	21						393	7.6	Minimum value
					.04					166	0		60				28	18	35	6.5	21						407	8.0	Mean value
					.13					168	0		64				30	18	36	7.8	22						424	8.5	Maximum value
Winchester Wasteway at Morrison Rd.	5/63-10/63 (11)				3					3	3		3				3	3	3	3	3						3	3	No. of obser.
					0					138	0		52				17	15	40	5.5	16						381	7.5	Minimum value
					0.2					175	1.5		61				26	16	44	6.0	18						431	8.0	Mean value
					0.7					224	5		66				40	18	47	6.6	21						514	8.5	Maximum value
Frenchman Hills Wasteway T 17, R 26	5/57-10/58 (11)				4					4	4		4				4	4	4	4	4						4	4	No. of obser.
					0					99	0		13				20	7	6	1.6	1						186	7.5	Minimum value
					.04					115	0		25				23	9	16	3.8	9						253	7.9	Mean value
					.13					144	0		39				27	12	24	6.3	16						348	8.1	Maximum value
	5/60-10/60 (11)				3					3	3		3				3	3	3	3	3						3	3	No. of obser.
					0					120	0		35				23	11	20	13	3.1						305	8.1	Minimum value
					0.3					143	1		47				27	13	26	16	3.2						360	8.4	Mean value
					0.8					175	2.4		58				32	18	33	22	3.5						454	8.7	Maximum value

TABLE B-1 (Continued)

Sampling Station	Date	DO mg/l	% DO Sat.	Concentration (mg/l)																					Turbidity	Coliform MPN/100 ml.	Conductivity umhos @ 25°C	pH	
				NH3-N	NO_3-N	Org. N	PO_4	Soluble Phosphate	Total Alkalin.	HCO_3	CO_3	Tot.Hard. as $CaCO_3$	SO_4	Total Solids	Dissolved Solids	Fe	Ca	Mg	Na	K	Cl	F	SiO_2	Color					
Frenchman Hills Waste-way, T17, R 26 (Cont.)	May-Oct. 1961-62 (11)				6					6	6		6				6	6	6	6	6						6	6	No. of obser.
					0					133	0		49				15	16	30	3.1	19						390	7.4	Minimum value
					0.8					161	0.8		65				31	20	37	3.7	24						450	8.1	Mean value
					1.7					187	4.8		79				39	23	43	4.7	28						525	8.4	Maximum value
	5/63-10/63 (11)				3					3	3		3				3				3						3	3	No. of obser.
					.13					122	0		48				31				16						326	7.9	Minimum value
					.7					166	0		65				35				22						443	8.1	Mean value
					1.2					199	0		78				38				26						526	8.4	Maximum value
Lind Coulee Wasteway	5/57-10/58 (11)				4					4	4		4				4	4	4	4	4						4	4	No. of obser.
					0					112	0		35				32	10	13	2.7	9						278	7.2	Minimum value
					0.4					126	0		45				36	11	17	4.4	14						338	7.6	Mean value
					1.4					137	0		63				40	13	23	5.5	21						420	8.0	Maximum value
	5/60-10/62 (11)				9					9	9		9				9	9	9	9	9						9	9	No. of obser.
					0					133	0		55				20	12	14	0	15						383	7.0	Minimum value
					1.2					148	0		72				39	16	25	4.2	20						445	7.6	Mean value
					2.1					174	0		95				47	25	39	7.1	27						536	8.1	Maximum value
	5/63-10/63 (11)				3					3	3		3				3	3	3	3	3						3	3	No. of obser.
					.4					125	0		55				36	11	20	0.8	13						331	7.4	Minimum value
					1.0					153	0		68				39	15	29	3.9	18						416	7.5	Mean value
					2.2					177	0		91				44	20	40	6.3	24						524	7.6	Maximum value
Scootenay Wasteway	5/57-10/58 (11)				4					4	4		4				4	4	4	4	4						4	4	No. of obser.
					0					81	0		11				20	5	3	1.1	0						150	7.6	Minimum value
					0					86	0		12				21	5	4	2.2	0.6						160	7.8	Mean value
					0					89	0		13				22	6	4	3.9	1.4						165	7.9	Maximum value
	5/60-10/62 (11)				9					9	9		9				9	9	9	9	9						9	9	No. of obser.
					0					77	0		12				20	5	2	0	0						144	7.1	Minimum value
					0					81	0		13				21	5	3	1.4	0.8						156	7.9	Mean value
					0					87	0		16				24	6	5	1.9	2.5						165	8.3	Maximum value
	5/63-10/63 (11)				3					3	3		3				3	3	3	3	3						3	3	No. of obser.
					0					72	=0		12				21	5	3	0.8	0						146	7.7	Minimum value
					0					77	0		14				21	5	3	1.6	0.3						151	7.9	Mean value
					0					81	0		16				21	6	4	2.4	1						156	8.0	Maximum value

TABLE B-2

Columbia River Water Quality Summary in Vicinity of Columbia Basin Irrigation Project

(Data Source: National Water Quality Network, USPHS)

Sampling Station	Date	Total Radioactivity μμc/1			Total Carbon Chloroform Extract microgr./l.	Temp. °C	DO mg/1	pH	Cl mg/1	Alk. mg/1	Hard. mg/1	Color	Turbidity	SO_4 mg/1	PO_4 mg/1	Total Diss. Solids mg/1	Coliform per 100 ml.	B mg/1	F mg/1	K mg/1	Na mg/1	BOD mg/1	COD mg/1	
		Alpha	Beta	Sr90																				
Columbia River at Pasco, Wash.	Nov. 1957	20	37		8	48	43	48		48	48	48	48				17					38	6	No. of obser.
	-	1	48		17	6.7	7.6	7.8		43	56	3	1				13					0.3	5.5	Minimum value
	Sept.1958	1	935		27	14.3	9.9	8.1		58	71	8	5				35					1.4	8.9	Mean value
		14	1,696		67	22.0	11.7	8.3		78	83	18	13				4,800					2.7	13.4	Maximum value
	Oct. 1958	10	47		12	49	47	48		49	49	49	49					2	2	2	2	47	10	No. of obser.
	-	0	85		12	5.0	7.3	7.5		55	59	2	1					0.07	0	0.6	2.9	0.2	4.6	Minimum value
	Sept.1959	2	488		29	12.2	10.5	7.9		68	73	10	7					0.09	0.07	0.8	3.0	1.5	7.1	Mean value
		7	1,228		73	20.0	12.7	8.2		78	84	68	30					0.11	0.14	1.2	3.0	3.7	12.5	Maximum value
	Oct. 1959	18	50		14	45	46	41		46	46	46	46									46		No. of obser.
	-	0	20		18	4.0	9.0	7.7		62	62	3	2									0.2		Minimum value
	Sept.1960	0.2	487		38	10.8	11.4	8.1		70	72	6	5									1.7		Mean value
		1	1,624		69	20.0	13.3	8.6		82	80	20	20									3.1		Maximum value
	Oct. 1960	12	47	2	14	51	52	50		52	52	52	52				7	2	2	2	2	51		No. of obser.
	-	0	39	1.0	13	5.0	8.7	7.8		60	60	6	1				1	0.03	0.10	1.3	2.8	0.1		Minimum value
	Sept.1961	1	520	1.0	23	12.5	10.9	8.1		71	70	10	7				41	0.06	0.13	1.8	2.8	1.6		Mean value
		2	1,191	1.1	47	22.0	12.7	8.5		77	78	24	30				190	0.10	0.16	2.3	2.8	3.3		Maximum value
Columbia River at Wenatchee, Wash.	Oct. 1958	8	47		8	50		49		49	49					49	12	2	2	2	2		5	No. of obser.
	-	0	0		15	3.1		6.9		51	50					38	3	0.03	0.16	0.6	1.8		3.7	Minimum value
	Sept.1959	0.1	35		27	10.8		7.8		59	63					114	25	0.04	0.16	0.8	2.2		6.0	Mean value
		1	292		37	17.6		8.1		76	91					308	90	0.04	0.17	1.0	2.5		8.1	Maximum value
	Oct. 1959	12	32		10	50		50		50	50					48	4							No. of obser.
	-	0	0		12	2.5		7.4		48	56					56	3							Minimum value
	Sept.1960	0.5	2.1		22	10.2		7.9		57	65					90	48							Mean value
		2	16		32	18.6		8.2		63	74					118	130							Maximum value
	Oct. 1960	12	15		10	50		51	36	51	51	43	36	41	15	34	25	2	2	2	2			No. of obser.
	-	0	0		16	4.1		7.6	2	46	55	0	0	7	0	66	3	0.03	0.10	1.3	2.3			Minimum value
	Sept.1961	0.8	2.1		26	11.6		8.0	5	55	62	3	1	15	0.1	86	410	0.06	0.31	1.8	2.3			Mean value
		2	6		36	19.5		8.2	25	63	112	5	5	30	0.3	121	7,300	0.09	0.52	2.2	2.3			Maximum value

TABLE B-3

GROUND WATER QUALITY DATA

Wells sampled are numbered by township/range-section and 40-acre subdivision. Example: Well number 10/29-10D1 is in township 10, range 29, section 10 and in the north-west 40-acre subdivision of the section (see below for section lettering system).

D	C	B	A
E	F	G	H
M	L	K	J
N	P	Q	R

TABLE B-3

Ground Water Quality Summary

Columbia Basin Irrigation Project

Reference	Well Sampled	Date Sampled	Depth (ft.)	milligrams per liter																			Spec. Cond. umhos @25°C	Water Level	
				Fe	Mn	Ca	Mg	Na	K	HCO_3	CO_3	SO_4	Cl	F	B	Alkalin.	Dis.Sol.	Hardness	NO_3-N	NO_2-N	NH_3-N	pH		Ft.Bel. Surface	.Date
1	10/29-10D1	9/53	618			32	18	31	5.5	141		86	12	0.5			352	154	0.1			8	446		
1	(USBR)	12/53	618			29	14	38	7.8	171	0	63	12	0.8			298	130	0			7.8	409	331	12/53
13		8/17/60						72	10			59	7			145		114	0	0	0.1		418	321	6/58
13		8/22/61						39	8.7			61	5			146		118	0				417		
13	11/30-11B2	1/20/60	118																4.9					114	10/40
13	(City of	8/25/60						57	7.4			76	32			138		217	6.9	0	0		570		
13	Eltopia)	8/16/61				58	24	31	7.4			100	41			132		243	8.3				641		
13		8/1/62											36						10.5				641		
11	11/30-11C1	9/51	614			10	4.4	64	13.3	160	0	41	18				288	43	1.4			8.4	401	355	9/55
11	(USBR	10/58				116	58	16	2	124	0	253	133				796	530	6.9			8.1	1,058		
11	Eltopia	1/20/60																	13.1						
11	Camp)	9/23/60																316	15.1				1,850		
11		1/61								324									12.2				729		
11		4/30/62								353								353	10.5						
1	11/32-20A1	3/13/58	156	.25	.2	51	18	31	2.5	241	0	53	11	.2	.04		331	200	.04				503	121	9/56
13	(Domestic	8/17/60						63	2.4			54	12			197		200	.04		0.08		510		
13	Farm Well)	8/22/61						32	2.2			54	10			202		200	.01				503		
1	12/29-28F1	1/53	699	.17		9.4	4.6	46	6	116	3	35	11	1.0			230	42	0.1			8.0	282	493	1/53
1	(USBR)	11/56				9.0	4.5	45	7	108	0	40	12	4.7			236	41	0.3			7.4	310		
13		8/61				1.6	0.2	83	8			30	16			140			.04				400		
1	12/30-5B1	3/6/56	458			31	21	15	3.9	156	0	30	21	0.7			278	164	2.2			7.8	381	355	2/56
13	(USBR)	8/25/60						24	4.2			40	16			124		162	3.4	0	0		407	236	4/58
13		8/1/62											16						3.5						
1	12/32-28B1	3/13/58	792	.03	0	12	6.1	29	5.8	125	0	15	8.2	0.9	0.3		215	55	0.1			8.0	256	492	9/56
13	(Domestic	9/19/60						56	6.8			16	6.8			104		42	0.1	0	0.03		250		
13	Fall Well)	8/22/61						31	5.9			14	4.2			102		54	0.1				249		
1	13/29-26B1	12/10/54	175			35	22	24	5.5	135	0	71					340	178				7.7	458	139	11/54
13	(USBR)	8/25/60						71	8.4			64	27			280		312	4.8	0	0.01		748	100	5/58
13		8/16/61				67	35	34	7.4			68	29			274		312	4.4				730		
13		8/1/62											30						4.2						
1	13/30-36C1	12/29/50	340			25	14	17	7.4	169	0	18	17	0	.04		240	120	0.3			8.2	311	190	12/50
13	(USBR	8/25/60						47	6			18	8			134		116	1.3				326		
13	Mesa Camp)	8/16/61				27	13	18	5.3			18	9			134		122	0.9				326		
11		4/30/62																131	0.8						

TABLE B-3 (Continued)

Reference	Well Sampled	Date Sampled	Depth (ft.)	milligrams per liter																		pH	Spec. Cond. umhos @ 25°C	Water Level	
				Fe	Mn	Ca	Mg	Na	K	HCO_3	CO_3	SO_4	Cl	F	B	Alkalin.	Dis.Sol.	Hardness	NO_3-N	NO_2-N	NH_3-N			Feet Below Surface	Date
1	13/32-14M1	9/29/50	535															120						515	6/41
13		9/19/60						51	4.5			20	9.3			130		91	0.5	.01	0.01		320		
1	14/29-9A1	4/23/53	860	.05		20	12	44	2.5	185	0	26	12	1	.04		266	99	0.1			8.0	378		
1	(US Govt.	9/29/55				20	10	43	7.6	186		24	11	0.9			265	91	0.2			8.1	386	587	9/55
1	Public	11/8/57		.21		21	12	43	8.1	187		30	13	0.9			271	102	0.4			8.0	398		
13	Supply)	8/25/60						72	8.5			28	11			151		90	0.6				394		
13		8/16/61					11	43	6.9			31	14			152		101	0.8				405		
1	14/30-8G1	8/52	371			29	23	23	4.3	180	0	47	27	0.6				167	0.1			8.0	449	225	7/52
1	(USBR)	3/13/58		.8	.02	140	106	42	7.8	294	0	368	128	0.3	.08		1180	460	22			7.9	1,570	110	5/58
13		8/25/60						54	5.6			161	78			278		539	9.6	0	0.03		1,100		
13		8/16/61				105	60	23	4.4			158	62					508	9.2				1,031		
13		8/1/62											58			283			7.8						
1	14/30-10P1	7/52	433			26	19	30	5.1	162	8	43	15	1.1			280	143	1.0			8.5	396	300	3/52
13	(USBR)	8/25/60						84	7.5			120	21			215		278	6.8	.04	0.02		745	175	5/58
1	14/30-27J1	1/53	381			44	37	19	5.9	168	0	100	42	0.6			448	262	3.8			7.5	587	195	11/53
13	(USBR)	8/25/60						47	6.1			38	9			156		163	1.0				406	114	5/58
13		8/16/61				33	21	17	5			40	10			158		168	0.8				405		
1	14/31-36B2	4/28/42	286	.04		28	17	18	4.6	158	0	23	9.5	0.4			242	140	2.9				337		
1	(City of	6/30/55		.03		35	20	13	3.9	146	7	23	20		.02		300	169							
1	Connell)	3/13/58		.05	0	30	15	11	2.5	151	0	14	5	0.4	.10		208	136	3.1				308		
1	14/33-18B1	8/4/58	542							167			5					100						484	4/53
13	(Domestic	8/17/60						36	4.1			11	2			120		112	0.5				267		
13	Farm Well)	8/22/61						9	3			10	2			122		114	0.3				336		
1	15/28-15D1	2/52	865			19	13	56	11	198	7	40	16	0.8			318	101	0.2			8.1	442	375	2/52
13	(Water Assn	9/5/60						95	18			40	12			149		56	.01	0	0.03		421		
13	Public Supl	7/27/61						57	13			44	12			155		69	.02				431		
1	15/28-24L1	2/52	398			29	22	24	4.7	193		47	13	0.8			292	163	0.1			8.2	421	342	1/52
1	(USBR)	12/53				32	19	30	4.7	173		64	15	0.6			290	158	1.0			7.7	431	281	11/53
1		9/18/56				2	0	222	1.6	176	0	236	68	0.7			690	5	1.7			8.0	1,100		
13		10/60				96	45	59	8.0			197	41			215		376	2.4				911		
13		7/27/61						46	7.4			189	41			228		374	1.9				883		
13		8/1/62											42						2.0						
1	15/30-36A1	3/13/56	492	.04		20	16	25	3.1	175	0	20	9.9	1			278	116	0.2			8.1	338	425	2/56
13	(USBR)	8/25/60						55	5.4			18	5.0			143		106	.24	0	0.01		328	390	6/58
13		8/16/61				20	14	25	4.3			18	5.5			143		108	.29				322		

TABLE B-3 (Continued)

Reference	Well Sampled	Date Sampled	Depth (ft.)	milligrams per liter																		pH	Spec. Cond. umhos @ 25° C	Water Level	
				Fe	Mn	Ca	Mg	Na	K	HCO_3	CO_3	SO_4	Cl	F	B	Alkalin.	Dis.Sol.	Hardness	NO_3-N	NO_2-N	NH_3-N			Feet Below Surface	.Date
1	15/32-1J1 (Domestic Farm Well)	8/8/58	353							179								35					295	195	3/55
13		9/19/60						71	8.2			11	7.5			132		31	.13				298		
13		8/22/61						50	7.8			15	5.8			133		34	.03				300		
1	16/23-34C1 (Railroad, Public Sup.)	1944	85			30	7	14*	*	137		11	5				175	104						64	8 /50
13		9/5/60						36	3.1			16	3			101		106	.4	0	0.02		249		
13		7/27/61						8	2.2			17	4			86		91	.6				216		
1	16/30-18A1 (USBR)	6/55	392			12	10	67	11	197		38	23	1		117	332	71	.1			7.6	467	243	6/55
13		8/30/60						49	2			22	7			115		92	.2				292	138	6/58
13		10/6/60						48	2			32	22			122		100	.8				345		
13		8/9/61						26	1.8			41	16					128	.6				370		
13	16/29-34R1 (City of Othello)	5/4/61	901	0		3	.8	81	12	170	6	27	14	2.8			293	10	0					278	4/57
1	16/29-6P1 (Domestic Farm Well)	8/27/51				66	37	121	20	492	0	106	56		.22			317				7.6	1,087	17	10/50
13		8/30/60						50	10.6			52	22			207		84	.25				557	12	5/58
13		8/9/61				21	11	86	9.3			52	24			214		86	.07				581		
1	17/26-28Q1	4/27/42	404	.44		32	18	43	13	182	0	55	40	0.5			337	154	.1				514		
13		9/5/60						77	13			73	26			144		136	.7				521		
11	17/27-10M	10/8/58				32	36	30	3.1	264	0	58	5						4.9			8.0	557		
11		10/20/60				35	36	28	2.3	257	0	50	7						7.8			8.2	549		
11		10/12/61				34	35	28	3.1	264	0	51	3						7.6			7.7	530		
11		10/18/62				34	34	31	3.9	254	0	50	5						7.6			7.7	497		
11		5/16/63				39	34	30	3.1	244	0	51	9						8.7			7.8	552		
11		10/10/63				32	35	27	3.1	255	0	50	3						7.1			7.8	520		
1	17/27-10M1 (Domestic Farm Well)	5/10/56	40			29	37	29	2.7	259		52	3.5					224	4.2			7.4	532		
1		5/20/57				31	37	30	2.3	261		54	7.8		.02			229	4.4			8.1	515		
13		8/30/60						54	3.1			52	6.5			207		228	7.9	0	0		558		
13		7/27/61						29	2.7			54	5			212		226	4.3				527		
13		8/1/62											7						9.5						
1	17/27-31D1 (USBR)	1951	810			35	19	56	16	209	0	56	53	0.5			394	165	0			8.2	601	200	2/51
13		8/30/60						87	17			57	44			178		154	0.05	0	0		680		
13		7/27/61						54	15			62	46			175		157	0.79				604		
1	17/28-12D1 (USBR)	4/25/51	270			33	19	38	8	210	0	43	25	0.7			314	160	0.1			7.9	483	157	3/51
13		8/30/60						58	6			34	18			193		176	0.4				478	74	5/58
13		8/9/61				44	19	32	5			35	20			202		189	0.1				500		

*Total of sodium and potassium.

TABLE B-3 (Continued)

Reference	Well Sampled	Date Sampled	Depth (ft.)	milligrams per liter																		pH	Spec. Cond. umhos @ 25°C	Water Level	
				Fe	Mn	Ca	Mg	Na	K	HCO_3	CO_3	SO_4	Cl	F	B	Alkalin.	Dis.Sol.	Hardness	NO_3-N	NO_2-N	NH_3-N			Feet Below Surface	Date
14	17/30-10P1 (City of Warden)	11/13/57	685			18	8	34	8	173		12	5.8				230	76						168	9/53
14		7/16/63				19	10	25	12	174		16	6.9	0.8			223	82	2.9	.03		8.0	318		
1	17/31-8R1 (USBR)	12/53	155			22	15	21	3.9	137		29	9.2	0.6			228	117	0.1			7.0	293	62	12/53
13		8/30/60						38	1.3			13	2.5			100		92	0.1	0	0		222	58	5/58
13		8/9/61				16	18	13	1.4			18	4.5			120		112	0.2				270		
1	18/23-36H1	5/8/50	670			32	22	30	6.6	220	0	43	13	0.6	0		314	170	0.1				438	295	1950
13		8/22/60						42	2.4			34	34			139		208	3.4	0	0		467		
13		7/17/61						14	2.1			45	46			134		230	4.0	0	0		499		
13		8/1/62											61						4.7						
1	18/24-6H1 (USBR)	1/55	330			39	25	9.9	2.3	148	0	35	35	0.6			262	200	2.7			7.8	445	188	7/54
13		8/22/60						39	2.0			36	26			132		196	3.4	0	0		443	45	4/58
13		7/17/61						12	1.7			47	34			136		218	3.4	0	0		454		
13		8/1/62											48						4.1						
11	18/25-4A	10/8/58	126			100	45	20	10.9	265	0	216	15						9.5			7.8	912		
11		10/20/60				57	45	20	7.1	107	10	220	12						8.7			8.5	712		
11		10/12/61				88	40	17	5.5	240	0	174	11						8.9			8.1	764		
11		10/18/62				60	38	23	3.9	247	0	147	7						0			7.7	652		
11		5/16/63				52	34	23	6.3	235	0	122	7						0			7.8	575		
11		10/10/63				89	42	16	5.5	210	0	168	16						15.3			7.7	756		
11	18/26-28F	10/8/58	-			46	24	24	21	525	0	2	9						0			7.2	890		
11		10/20/60				41	26	21	17	393	0	13	9						0.5			7.3	617		
11		10/12/61				43	22	23	16	361	0	2	9						0			7.6	575		
11		10/18/62				38	20	23	17	302	0	6	9						0.5			7.5	492		
11		5/16/63				38	19	23	16	276	0	3	12						1.6			7.5	436		
11		10/10/63				35	20	23	16	266	0	5	9						2.2			7.7	441		
1	18/28-36D1 (USBR)	2/52	218			38	24	23	4.7	206	0	33	13	0.6			360	193	10.7			8.3	508	96	8/55
1		5/10/56				38	24	24	3.9	181	0	35	16						11.3			7.6	491	81	5/58
11		10/8/58				41	24	24	7.0	173	0	39	26						11.3			8.1	513		
11		10/20/60				44	26	23	3.9	154	0	48	31						8.9			8.2	546		
11		10/12/61				44	28	20	3.2	156	0	55	29						9.1			8.2	540		
11		10/18/62				46	25	20	4.7	151	0	59	29						6.9			8.0	512		
11		5/16/63				42	27	21	4.7	160	0	57	31						7.6			8.2	498		
11		10/10/63				45	27	21	5.5	143	0	59	29						8.5			7.5	528		
1	18/29-17P1 (USBR)	2/52	342			18	14	36	11	171	0	29	18	0.8			274	102	2.1			8.7	380	190	1/52
13		8/30/60						56	3.9			60	43			150	258		13.4				633	89	5/58
13		8/9/61				42	34	29	3.2			68	52			140	277		16.3				684		
13		8/1/62											52						14.2						
1	18/30-16R1 (USBR)	11/53	185			22	16	33	2.7	179	0	30	18	1.3			288	121	0.1			7.5	376	144	11/53
13		8/30/60						78	5.7			131	44			130		258	10.8				734	65	5/58
13		8/9/61				55	28	48	4.3			125	42			140		252	10.1				717		
13		8/1/62											50						12.3						

TABLE B-3 (Continued)

Reference	Well Sampled	Date Sampled	Depth (ft.)	milligrams per liter																		pH	Spec. Cond. umhos @ 25° C	Water Level	
				Fe	Mn	Ca	Mg	Na	K	HCO_3	CO_3	SO_4	Cl	F	B	Alkalin.	Dis.Sol.	Hardness	NO_3-N	NO_2-N	NH_3-N			Feet Below Surface	Date
1 13 13	19/26-1R1 (USBR)	9/18/56 8/30/60 8/9/61	459	0		18 32	4.3 13	33 63 32	2.7 5.8 4.5	111	0	42 26 25	7.8 5.0 5.2	0.6		171 175	212	63 128 133	0.1 0.5 0.6	.07	0.01	8.0	314 392 395	200 205	4/56 9/58
1 15	19/28-15Q1 (Moses Lk. Well 3)	8/2/55 8/61	909	.02 .02	0.8	6 4	2 4	69 26	11 15	142 160		28 28	16 22	1.7		131	294 229	16	0.2	.03			392	25 35	1951 6/57
1 15	19/28-23D8 (Moses Lk. Well 7)	4/21/57 12/59	956	.1 .02		4 8	1 2	70* 64	* 10	171 155	5 4	17 19	16 17	2.5			260 264	13 29	0.9				363	25	6/57
15	19/28-23J1 (Moses Lk. Well 5)	8/61	950	0	0	25	14	52	10	170		36	20	1.0		139	18	112	8.2				427	91	9/56
15	19/28-28K4 (Moses Lk. Well 4)	8/61	1000	.02	0	8	3	76	23	170		24	20	1.7		139	131	28	0.2				423	29	7/53
1 13 13	19/29-22C1 (USBR)	1/52 8/15/60 6/21/61	352			36	21	37 24 23	8.2 2.3 2.3	149	0	82 14 13	46 0.2 0.2	0.5		87 87	368	176 38 52	0.11 0.08	0 .001	0.02 0.01	7.5	572 201 187	216 170	12/51 5/58
1 13 13 13	19/29-34D2 (Domestic Farm Well)	4/29/50 8/15/60 6/21/61 8/1/62	285	.03	0	32	20	43 91 65	6.4 3.6 4	183		58 64	26 5 9	0.5		155 180	345	162 78 124	3.6 1.3 4.1 1.3	0 .01	0.02 0.04	7.8	508 403 493	30 33	6/55 5/58
1 1 13 13	19/30-32N1 (USBR)	4/4/51 8/19/57 8/15/60 6/21/61	351	0		16 42	1.2 20	79 47 27 33	13 0 2 2			50 95 32 55	20 56 3 10	1.1 0.5		110 132	350 390	45 187 80 132	0 0.7 0.3 1.1			8.1 7.4	463 551 286 374	223 128	1/51 5/58
13 13	19/31-22D1 (Domestic Farm Well)	8/15/60 9/12/60	25					111 130	6.2 6.8			149 165	85 10			426 404		472 542	11.1 14.5	.001 .001	0.02		1,326 1,390		
1 13 13 13	20/23-10N1 (USBR)	9/53 8/22/60 7/17/61 8/1/62	351			32	19	27 67 40	3.9 7.7 7.5	182	0	53 77 81	15 63 71 76	0.4		144 144	284 232 246	158	0.1 3.6 3.3 3.6	0 9	0.03 0.04	7.8	427 660 645	208 129	8/53 4/58
1	20/24-7R1 (City of Quincy)	8/3/55 10/6/60	431	.01		32	10	25	4.3	153		29 28	17				248	121 110	1.9					275 41 30	10/39 4/58 9/63

*Total of sodium and potassium.

TABLE B-3 (Continued)

Reference	Well Sampled	Date Sampled	Depth (ft.)	milligrams per liter																		pH	Spec. Cond. umhos@25°C	Water Level	
				Fe	Mn	Ca	Mg	Na	K	HCO_3	CO_3	SO_4	Cl	F	B	Alkalin.	Dis.Sol.	Hardness	NO_3-N	NO_2-N	NH_3-N			Feet Below Surface	.Date
1	20/25-3R1	8/5/53	168							122								185						123	9/53
13	(Domestic	8/22/60						94	5.4			428	38			172		574	4.7	0	0.02		1,220	81	4/58
13	Farm Well)	7/17/61						26	3.8			198	36			139		360	6.0	0	0.04		752		
13		8/1/62											33						7.8						
1	20/25-29H1	12/29/50	175			24	16	22	3.5	173	0	16	19	0.1			234	126	1.7				369	152	11/50
13	(USBR)	8/22/60						53	3.2			18	4			140		118	0.1	.001	0.02		294	84	5/58
13		7/17/61						14	2.8			21	4			132		128	0.2	.001	0.04		288		
1	20/30-10B1	7/24/50	145										10					130						90	1949
13	(Domestic	8/15/60						13	3.4			23	20			109		160	11.6	.001	0.01		421		
13	Farm Well)	6/21/61						14	3.2			23	20			109		170	10.9	.001	0.03		393		
13		8/1/62											16						9.7						
1	21/26-8M1	7/22/55	1000	.01		16	13	22	3	146		12	7			201	180	98				7.9		135	5/52
13	(City of	9/5/60						64	9			22	4			86			0.01	0	0.01		314		
13	Ephrata,	6/21/61						32	8			23	4			84			0.01	.001	0.02		295		
	No. 3)																								
1	21/28-23D1	4/25/51	150			31	19	18	5.1	133	0	31	26	0.5			282	155	22			7.5	399	88	3/51
13	(USBR)	8/15/60						38	7.2			81	19			199		222	3.1	0	0.02		608	68	5/58
13		6/21/61						48	8.6			135	36			234		320	3.6	.001	0.10		779		
13		8/1/62											17						3.3				779		
1	22/26-24L1	7/22/55	435	.13		15	15	20	4	156	2	18	7		.03		251					7.8		120	3/51
13	(City of	8/15/60						15	3			36	12			118		138	2.2	.007	0.01		356		
13	Soap Lake)	9/12/60						60	3			31	10			109		120	1.3	0	0.03		315		
1	22/28-10A3	6/50	260										6					135						110	6/49
13	(Wn.Power	8/15/60						33	5			54	10			216		206	00.3	0	0		536		
13	Co.)	6/21/61						33	5			52	10			208		198	0.3						
13		8/1/62											8						0.2	.001	0.04		480		
11	Irr. Unit	9/61	128															572	296					96	1963
	115,Blk.14																								
	(12/30-19)																								
11	Irr. Unit	9/60	83															734	109						
11	12, Blk.19	1/61																835	146				2,008	40	1963
11	(13/29-25)	4/30/62																815	115						
11	Irr. Unit	4/30/62	93															151	33					22	1963
	134,Blk.19																								
	(13/30-30)																								

TABLE B-4

PESTICIDES IN COLUMBIA BASIN WATER SAMPLES DURING THE 1961 IRRIGATION SEASON (Reference X-18)

Type/Location	Pesticide	Concentration (parts per trillion)
Irrigation return flow Quincy area	Aldrin DDT	0.25 1.03
Irrigation return flow Moses Lake area	DDT 2,4-D isopropyl ester	4.0 18.0
Irrigation water-West Canal near Quincy	DDT	0.7
Irrigation return flow Quincy area	Aldrin DDT	0.1 trace
Irrigation return flow Moses Lake area	DDT 2,4-D isopropyl ester	16 3
Irrigation return flow Winchester Waste Way at U. S. Highway 10	DDT 2,4-D isopropyl ester	0.1 0.4
Irrigation return flow Crab Creek at Smyrna	DDT 2,4-D isopropyl ester	2.2 4.0
Well - from farm in the Moses Lake area	DDT	0.03
Well - from U.S.B.R. west of Moses Lake	DDT	0.05
Irrigation water in Quincy area	DDT 2,4-D isopropyl ester	0.1 0.3
Irrigation return flow Moses Lake area	2,4-D isopropyl ester DDT	1.1 0.5
Main Irrigation Canal below Long Lake Dam	2,4-D isopropyl ester DDT	0.5 0.1
Scootenay Lake Outlet	DDT	1.0

TABLE B-4, Continued

Type/Location	Pesticide	Concentration (parts per trillion)
Potholes Irrigation Canal South of Othello	2,4-D butyl ester	0.7
Outlet of the Scootenay Reservoir	DDT	0.8
Irrigation Water West Canal	DDT	0.06
Irrigation return flow in the Ringold Springs area	DDT	0.05
	2,4-D isopropyl ester	0.8
	Endrin	0.4
Irrigation return flow Ringold Springs area	Aldrin	2.0
Irrigation return flow Moses Lake area	2,4-D butyl Ester	4
	Endrin	57

TABLE B-5

PESTICIDES IN COLUMBIA BASIN WATER SAMPLES DURING THE 1962 IRRIGATION SEASON
(Reference X-18)

Type/Location	Pesticide	Concentration (parts per trillion)
Irrigation Canal west of Quincy	2,4-D isopropyl ester	Trace
	Aldrin	1.6
Irrigation return flow ditch--south of Quincy	2,4-D isopropyl ester	Trace
	Aldrin	0.8
	DDT	0.8
Return flow--Winchester Wasteway at U. S. Highway 10	2,4-D isopropyl ester	2.0
	Aldrin	0.4
Columbia River 1.2 mi so. of Wenatchee	2,4-D isopropyl ester	1.5
Return flow--Winchester Wasteway at U. S. Highway 10	Aldrin	0.2
Irrigation return flow ditch--south of Quincy	2,4-D isopropyl ester	1.8
	Aldrin	0.8
	DDT	0.9
Return flow--Winchester Wasteway at U. S. Highway 10	2,4-D isopropyl ester	0.1
	Aldrin	0.1
	DDT	0.2
	DDD	0.4
Bottom sediment from Crab Creek at State Highway 11G	DDT	9.6 µg/Kg
Bottom sediment from Moses Lake off Parker Horn	DDT	4.8 µg/Kg

TABLE B-6

SURFACE WATER QUALITY DATA GATHERED BY PHS IN 1964

Sampling Station	Date	NO_3-N mg/l	Conductivity u mhos @ 25° C	Pesticide Analysis 1/ Parts per Trillion (PPT) Chloroganic	Organic Phosphate	Herbicides
Long Lake Res.	5/25/64	0.00	158	nil	nil	nil
	6/20/64	0.02	166	trace DDD & DDT	nil	---
	7/24/64	0.00	153	nil	nil	nil
	8/24/64	0.04	147	nil	nil	2/
	10/3/64	0.00	152	nil	3/	nil
	11/1/64	0.06	163	nil	nil	2/
	11/23/64	0.01	164	nil	2/	2/
Potholes Canal at Headworks	5/25/64	0.42	497	nil	nil	nil
	6/20/64	0.40	494	nil	nil	---
	7/24/64	0.06	464	nil	nil	---
	8/24/64	0.16	409	nil	nil	trace 2-4D
	10/3/64	0.24	473	nil	nil	nil
	11/1/64	0.51	492	nil	nil	2/
	11/23/64	0.59	519	nil	2/	2/
Crab Creek near Smyrna	5/25/64	0.07	659	nil	nil	nil
	6/20/64	0.02	640	nil	nil	---
	7/24/64	0.00	660	116 ppt DDT	nil	nil to trace 2,4-D
	8/24/64	0.08	601	nil	2/	nil
	10/3/64	0.25	766	nil	3/	50-60 ppt 2,4-D
	11/1/64	0.46	872	nil	nil	2/
	11/23/64	0.59	953	nil	2/	2/

(continued)

TABLE B-6 (continued)

Sampling Station	Date	NO_3-N mg/l	Conductivity u mhos @ 25° C	Pesticide Analysis 1/ Parts per Trillion (ppt)		
				Chloroganic	Organic Phosphate	Herbicides
Ringold Wasteway	5/25/64	0.30	446	nil	nil	nil
	6/20/64	0.20	459	nil	nil	---
	7/24/64	0.05	421	nil	nil	nil to trace 2,4-D
	8/24/64	0.06	362	nil	nil	nil
	10/3/64	0.16	431	nil	nil	120 ppt 2,4-D & 2/
	11/1/64	0.49	424	nil	nil	1,370 ppt 2,4-D
	11/23/64	0.06	491	nil	2/	2/
Potholes Canal near Mouth	5/25/64	0.34	456	nil	Trace Malathion	nil
	6/20/64	0.20	465	nil	nil	---
	7/24/64	0.11	435	nil	nil	nil to trace 2,4-D
	8/24/64	0.11	380	nil	nil	nil
	10/3/64	0.17	432	nil	nil	60-70 ppt 2,4-D
	11/1/64	2.30	817	nil	nil	800 ppt 2,4-D
	11/23/64	3.10	808	nil	2/	2/

1/ Nil - less than the lower limit (about 50 parts per trillion) of sensitivity of the analytical instrument.

2/ Unidentified peaks on the gas chromatograph.

3/ Parathion, disappeared on standing.

TABLE B-6A
GROUND WATER QUALITY DATA GATHERED BY PHS IN 1964

Sampling Station	Date	NO3-N mg/l	Conductivity u mhos @ 25° C	Pesticide Analysis 1/ Parts per Trillion (ppt) Chloroganic	Organic Phosphate	Herbicides
Well 21/28-23D1	5/25/64	1.9	950	nil	nil	nil
(USBR)	6/20/64	2.9	827	nil	nil	---
Depth 150'	8/24/64	2.7	576	nil	nil	nil
	10/3/64	3.1	613	nil	nil	nil
	11/1/64	4.0	592	nil	nil	2/
	11/23/64	3.8	604	nil	nil	2/
Well 20/25-21A2	5/25/64	5.2	582	nil	Trace Malathion	nil
(USBR)	6/20/64	23.2	553	nil	nil	---
Depth 652'	7/24/64	8.8	508	nil	nil	nil
Curt Smith or	8/24/64	8.4	429	nil	nil	2/
Winchester	10/3/64	6.5	514	nil	nil	nil
Development Farm	11/1/64	8.0	543	nil	nil	nil
	11/23/64	9.6	548	nil	2/	nil
City of Quincy	5/25/64	1.6	370	nil	Trace Diazinon	nil
Well 20/24-7R1	6/20/64	1.8	375	150 ppt DDT	Foreign sulfur comp.	---
Depth 431'	7/24/64	0.6	354	nil	nil	nil
	8/24/64	1.9	335	nil	2/	2/
	10/3/64	1.7	383	nil	nil	nil
	11/1/64	2.2	393	nil	nil	2/
	11/23/64	2.0	396	nil	nil	2/

(continued)

TABLE B-6A (continued)

Sampling Station	Date	NO_3-N mg/l	Conductivity u mhos @ 25° C	Pesticide Analysis 1/ Parts per Trillion (ppt)		
				Chloroganic	Organic Phosphate	Herbicides
Well 18/30-16R1	5/25/64	9.2	664	nil	Trace Malathion	nil
(USBR)	6/20/64	12.0	695	150 ppt DDT	nil	---
Depth 185'	7/24/64	8.1	712	nil	nil	nil to trace
	8/24/64	8.9	---	nil	nil	Trace 2-4, 5T
	10/3/64	13.7	703	nil	nil	nil
	11/1/64	12.2	698	nil	nil	nil
	11/23/64	12.6	696	nil	2/	nil
Wahluke Camp	5/25/64	0.04	373	nil	nil	nil
Well 15/28-35P1	6/20/64	0.00	368	nil	nil	---
Depth 840'						
13/29-25	6/11/64	67.1	1,640	Trace DDT	nil	---
(Paris Well)	6/20/64	60.5	1,635	nil	nil	---
Depth 83'	7/24/64	90.4	1,612	nil	nil	nil to trace 2,4-D
	8/24/64	59.9	1,404	nil	nil	nil
	10/3/64	65.5	1,592	nil	nil	2/
	11/1/64	66.1	1,633	nil	nil	nil
	11/23/64	83.9	1,586	nil	2/	nil
City of Mesa	5/25/64	2.1	497	nil	Trace Malathion	nil
Well 13/30-26J3	6/20/64	4.8	495	nil	nil	---
Depth 100'	7/24/64	3.6	510	78 ppt DDT	nil	nil to trace 2,4-D
	8/24/64	3.9	512	nil	2/	trace 2,4-D
	10/3/64	4.6	513	nil	nil	nil
	11/1/64	4.7	519	nil	97 ppt Ethion	2/
	11/23/64	5.4	508	nil	nil	2/

(continued)

TABLE B-6A (continued)

Sampling Station	Date	NO_3-N mg/1	Conductivity u mhos @ 25° C	Pesticide Analysis 1/ Parts per Trillion (ppt)		
				Chloroganic	Organic Phosphate	Herbicides
Block 12 Water Association (13/30-29A1) Depth 540'	6/11/64	8.2	806	Trace DDT	nil	---
	6/20/64	8.3	798	nil	Foreign sulfur comp.	---
	7/24/64	8.6	827	nil	nil	nil
	8/24/64	6.5	740	nil	nil	2/
	10/3/64	8.1	839	nil	nil	nil
	11/1/64	11.1	873	nil	nil	nil
	11/23/64	10.6	853	nil	2/	2/
Basin Water Dist. Well 13/30-30A1 Depth 385'	6/11/64	6.0	634	nil	nil	---
	6/20/64	7.8	671	nil	nil	---
13/30-30 (Jarrett Well) Depth 93'	6/11/64	33.0	1,320	nil	nil	---
	6/20/64	41.9	1,334	nil	nil	---
Jarrett Spring	6/11/64	7.2	1,040	---	---	---
Apex Water Ass'n. (12/29-22) Depth 80'	6/11/64	8.9	681	Trace DDT	Trace Parathion	---
	6/20/64	8.2	698	nil	nil	---
	7/24/64	7.8	726	nil	nil	nil
	8/24/64	7.4	640	nil	nil	2/
	10/3/64	8.6	729	nil	nil	nil
	11/1/64	11.5	743	nil	nil	nil
	11/23/64	29.5	755	nil	2/	nil

(continued)

TABLE B-6A (continued)

Sampling Station	Date	NO_3-N mg/1	Conductivity u mhos @ 25° C	Pesticide Analysis [1] Parts per Trillion (ppt)		
				Chloroganic	Organic Phosphate	Herbicides
Well 12/30-19	5/25/64	173.0	1,664	Trace DDD	Trace Parathion	nil
(Arthur Ward)	6/11/64	127.0	1,820	55 ppt DDT	nil	---
Depth 128'	6/20/64	106.0	1,601	nil	nil	---
	7/24/64	178.0	1,751	110 ppt DDT	nil	130 ppt 2,4-D
	8/24/64	111.0	1,680	nil	nil	nil
	10/3/64	90.0	1,447	nil	nil	nil
	11/1/64	54.0	1,318	nil	nil	nil
	11/23/64	52.4	1,112	nil	[2]	nil
City of Eltopia	5/25/64	3.1	594	nil [1]	nil	nil
Well (11/30-11B2)	6/20/64	5.8	592	120 ppt DDT	nil	---
Depth 113'	7/24/64	5.8	606	110 ppt DDT	nil to trace	260 ppt 2,4-D
	8/24/64	5.2	549	nil	[2]	nil
	10/3/64	6.2	632	nil	nil	nil
	11/1/64	7.1	647	nil	nil	nil
	11/23/64	7.2	632	nil	nil	nil

---

[1] Nil - less than the lower limit (about 50 parts per trillion) of sensitivity of the analytical instrument.

[2] Unidentified peaks on the gas chromatograph.

[3] Parathion, disappeared on standing.

TABLE B-7
PHYSICAL DATA - PHS GROUND WATER SAMPLING POINTS, 1964

Well Number	Owner	Altitude	Type of Well	Diameter (inches)	Depth of Casing	Water Bearing Material	Depth Below Land Surface Water Level	Date	Type of Pump & Horsepower	Use	Depth of Well (Feet)	Log	
												Material	To Depth
21/28-23D1	USBR	1,295	Drilled	8	85	Basalt	88 68	3/51 5/58	Turbine 3	Domestic	150	Sand, Basalt Sand, Basaltic gravel Boulders & Gravel Basalt	32 78 83 150
20/25-21A2	Curtis Smith	1,225	Drilled	12	198	Basalt	161 125 50 32 8	3/48 7/53 7/56 1958 1964	---	Domestic	652	See Page 485, Water Supply Bulletin No.8 USGS	
20/24-7R1	City of Quincy	1,305	Drilled	12	80	Basalt	275 41	10/39 4/58	Turbine 125 hp	Municipal Supply	431	NA	
18/30-16R1	USBR	1,206	Drilled	6	114	Basalt	144 65	11/53 5/58	Jet 3	Domestic	185	Silt Clay, Silty Sand, Basalt Basalt	60 83 113 185
15/28-35P1	Wahluke Camp, USBR	1,151	Drilled	10	---	Basalt	461 444	7/56 4/58	---	---	840	NA	
13/29-25	Carl Paris	--	Drilled	--	---	Sand, Gravel	40	--	---	Domestic	83		
13/30-26J3	City of Mesa	675	Drilled	12	100	Sand	31	9/53	Turbine 40 hp	Municipal Supply	100	Silt Clay, Silty Gravel	30 42 100
13/30-[a] 29A1	Block 12 Water Association	888	Drilled	8-6	305	Basalt	132	--	---	Domestic	540	Soil Gravel Clay Basalt	1 43 65 540
13/30-[b] 30AL	Basin Water Association	772	Drilled	8	---	Basalt	66	5/58	Jet 5	Domestic	385	Silt Gravel Basalt	13 33 350
13/30-30	Loris Jarrett	---	Drilled	--	---	Gravel	22	--	---	Domestic	93		
12/29-[c] 22	Apex Water District	---	Drilled	--	---	---	58	--	---	Domestic	80		
12/30-19	Arthur Ward	---	Drilled	--	---	Basalt	96	1963	---	Domestic	128	Clay, hardpan formation above well Basalt	22 200
11/30-11B2	City of Eltopia	578	Dug	6	115	Gravel	114	10/40	Plunger 4 hp	Municipal	113	Sand, fine with small gravel Clay Gravel, 2-4", coarse Sand	20 55 118

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a/ Serves 8 families; b/ Serves 40 people; c/ Serves 5 families.

APPENDIX C

Waste Disposal Regulations
for the
Columbia Basin Irrigation Project

(Reference 20)

REGULATIONS

The following regulations regarding the discharge of waste products to the canals, drains, wasteways, reservoirs and ground waters of the Columbia Basin Irrigation Project Area and the minimum standards for the treatment and disposal of sewage and industrial wastes in this area are hereby adopted and promulgated by the Washington Pollution Control Commission on this 19th day of February, 1954:

SECTION I--REGARDING DOMESTIC SEWAGE

A. Municipal and Community (Including School and Industrial Installations)

1. The discharge of raw sewage is prohibited under any circumstances.

2. The discharge of sewage treatment plant effluent into canals used for irrigation or stock watering is prohibited.

3. The discharge of sewage treatment plant effluent into drains, wasteways, or reservoirs, from which water is subsequently re-used in canals and laterals is prohibited, except by specific approval where special circumstances may require such discharge.

4. The disposal of sewage treatment plant effluent by land application methods is prohibited in locations where such disposal would adversely affect surface or ground water withdrawn for domestic purposes. Discharge

at extreme depths is prohibited.

(NOTE: Rules and Regulations of the State Board of Health prohibit irrigation of certain crops with sewage plant effluent.)

5. The minimum degree of treatment shall, in any case, be at least the equivalent of primary treatment and disinfection of the effluent.

6. Additional treatment, of a degree to be determined for each case, shall be provided where specific approval is granted for discharge to drains, wasteways, or reservoirs.

7. Additional treatment, of a degree to be determined for each case, shall be provided prior to disposal by land application methods when necessary to prevent possible contamination of ground and surface waters, or creation of a nuisance.

8. Notwithstanding Items 1 to 7, the degree of treatment, the provision for disinfection and method of disposal shall be a matter for the determination and approval of the Pollution Control Commission for each individual case.

B. Individual Farm Unit, Household or Other Source of Domestic Sewage Not Covered by Item A

1. No raw sewage or septic tank effluent shall be discharged to any canal, reservoir, drain or wasteway.

2. Households, farm units, schools, small business concerns or other sources of domestic sewage involving a limited number of persons shall provide sewage disposal facilities as prescribed by the County Health Department of the County in which the source is located.

SECTION II--REGARDING INDUSTRIAL WASTES

A. General Requirements

The following materials shall not be discharged to any drain or wasteway in excess of the concentration specified in each case. In no case will any of these materials be discharged to a canal:

1. No oils, tars, cleaning compounds or inflammables.
2 No phenols or phenolic-like compounds in excess of 0.05 parts per million.
3. No toxic materials such as:
    a. Fruit washing compounds
    b. Wood preservatives
    c. Insecticides--aldrin, rotenone, BHC, DDT, and all other similar products
    d. No weed killers
    e. Metallic or non-metallic products of metal processing or plating--acids, alkalies, cyanides, copper, etc.
4. Total salts, maximum 2500 parts per million
5. No salts or elements injurious to crops, soils or animals--aluminum, boron, arsenic, selenium, lead, manganese, etc.
6. No wastes with a pH less than 6.5 or greater than 8.5.
7. No floating solids.
8. No suspended solids in excess of that which can be removed by approved clarification or settling with a 2-hour detention period.

B. Ground Water Requirements

Wastes containing materials listed in Section II, A, Items 1, 2, 3, 4 and 5 above, shall not be disposed of in such a way as to enter the ground water.

C. Specific Requirements of Each Industry

1. Milk plants:
   a. Condenser water, cooling water and ice machine water may be discharged to drains or waterways, but not to canals.
   b. Wastes after proper treatment may be discharged to a drain or wasteway, if such discharge is approved by the Pollution Control Commission. The preferred methods of disposal of milk waste are:
      (1) Small receiving stations or bottling plants--connection to city sewers, or irrigation.
      (2) All others--irrigation or treatment by filtration or activated sludge.
   c. Milk waste may be used directly for irrigation under a controlled system whereby no nuisance is caused.
2. Canning, freezing and dehydration:
   a. Cooling waters may be discharged to drain or wasteway.
   b. Wastes shall be screened (20-mesh standard gauge) and disposed of by lagooning, irrigation or in leaching trenches.

3. Meat Packing:

   a. No wastes from slaughterhouses or meat packing plants shall be allowed to enter any drain or wasteway. Recommended methods of disposal are:

      (1) In all cases, blood, paunch manure, fleshings and grease shall be collected for rendering or some other type of utilization.

      (2) Wastes from small operations after complying with item (1) above may be accepted in city sewer system or may be treated by a combination grease trap-septic tank and drain field.

      (3) Wastes from large plants after complying with item (1) above may be treated by filtration and the effluent used for irrigation but not discharged to a canal, drain or wasteway.

4. Beet Sugar:

   a. No lime wastes, process waters or Steffen's waste shall be discharged to any drain or wasteway or in any way such that it may reach ground water.

   b. Flume water may be discharged to a drain or wasteway, but only after grit removal and re-use in the flumes with not more than 40 percent make-up. The waste water discharged to provide for the make-up must be settled in a tank equipped for continuous sludge removal and having a detention period of 2 hours.

   c. Flume water may be lagooned or used for irrigation.

5. Potato Washings:
   a. Wash water shall not be discharged to any wasteway or drain if it is possible to dispose of the water by irrigation on land.
   b. If wash water is to be discharged to any wasteway or drain, it must first be settled in a tank equipped with continuous sludge removal equipment and having a detention period of 2 hours or in a lagoon with a similar detention period with sufficient additional space for sand and solids accumulation.
   c. Wash water may be lagooned or used for irrigation.
6. Sand and Gravel Washing:
   a. No sand and gravel washings will be discharged to a drain or wasteway unless first passed through a lagoon with a settling period of 2 days.
7. Livestock Wastes
   a. Feed lots or hog wallows shall not be located within 100 feet of any wells used for public water supply.
   b. Feed lots or hog wallows shall be so located that surface runoff or waste water from the lot will not enter any canal, drain, wasteway or reservoir.
   c. Livestock and poultry carcasses shall not be deposited in any canal, drain, wasteway or reservoir.

8. Miscellaneous Operations:

   a. Garbage disposal areas and incinerators shall be so located to preclude discharge of drainage to any canal, drain, wasteway or reservoir.

   b. Operations not covered by these requirements will be considered individually and requirements established as the need arises.

APPENDIX D

MEMORANDUM OF AGREEMENT

MEMORANDUM OF AGREEMENT
between
UNITED STATES
DEPARTMENT OF THE INTERIOR
Bureau of Reclamation
and
UNITED STATES
DEPARTMENT OF HEALTH, EDUCATION, AND WELFARE
Public Health Service

Contract No.
14-06-100-3190

For a study and evaluation of water supply and water quality of the Columbia Basin Project, Washington.

THIS MEMORANDUM OF AGREEMENT, entered into this first day of November, 1963, between the BUREAU OF RECLAMATION, DEPARTMENT OF THE INTERIOR, hereinafter referred to as the Bureau, and the PUBLIC HEALTH SERVICE, DEPARTMENT OF HEALTH, EDUCATION AND WELFARE, hereinafter referred to as the Service, acting pursuant to the Act of June 17, 1902 (32 Stat. 388--the Reclamation Act), the Act of June 30, 1932 (47 Stat. 382--the Economy Act) and the Act of July 3, 1958 (72 Stat. 297--the Water Supply Act) and acts amendatory thereof and supplementary thereto,

WITNESSETH, That:

WHEREAS, the Bureau is making overall completion studies of the Columbia Basin Project in cooperation with various Federal and State agencies having responsibilities or special competence in matters affecting the project area; and

WHEREAS, the Bureau desires advice and assistance from the Service as to water supply and water quality of the Columbia Basin Project primarily as pertains to domestic, municipal and industrial uses, in which field the Service has responsibilities assigned by law; and

WHEREAS, because of the timetable of the overall completion studies the Service was unable to provide funds in its own budget for providing the said advice and assistance to the Bureau within the required time schedule,

NOW, THEREFORE, it is agreed as follows:

The Service will study and evaluate the water supply and water quality in the Columbia Basin Project area, except for irrigation water supply, determine the Project's effects upon these factors, and develop recommendations for maximum protection and use of such water supply resources under conditions of development of the project area.

The study will represent a coordinated, long-range approach by all agencies involved in the subjects covered by it.

The Service will prepare a final report embodying its findings and recommendations, including among other things the following:

(a) Assessment of the present water quality in the Columbia Basin Project area.

(b) An inventory and evaluation of present and future domestic, municipal and industrial water supply requirements.

(c) An inventory and evaluation of present and future domestic, municipal, agricultural and industrial waste disposal methods.

(d) Specific identification of future domestic, municipal and industrial water supply needs which could be satisfied by surface and ground-water supplies of the Columbia Basin Project.

(e) Recommendations for minimum flows in water courses and wasteways to maintain water quality.

(f) Determination of benefits for water quality control associated with the project.

(g) General assessment of the use of ground water for domestic purposes.

The report will be presented on two bases: (1) for the total Columbia Basin Project as presently contemplated of approximately 1,097,000 irrigable acres, and (2) for a lesser project of approximately 711,000 irrigable acres which would not include lands under the proposed East High canal.

The Bureau will make available to the Service such data as it may have in its files bearing on the study to be made hereunder, and will assist and facilitate the field investigations to be made by the Service to the extent feasible.

The Bureau agrees to reimburse the Service, upon receipt of billings submitted at least quarterly, for the purposes provided herein not to exceed the sum of $20,000.

The Service will furnish the Bureau, on or before June 1, 1964, with its final report as provided for herein in such reasonable number of copies as the latter may request. However, on or before December 31, 1963, the Service will furnish the Bureau with an interim reconnaissance type report of its findings and conclusions in such detail as may be agreed upon by the parties.

BUREAU OF RECLAMATION

By E. L. White
Acting Regional Director
Region 1, Boise, Idaho

PUBLIC HEALTH SERVICE

By R. F. Poston
R. F. Poston, Officer-in-Charge
Water Supply and Pollution Control
Program, Pacific Northwest
Portland, Oregon

APPENDIX E

VECTOR EVALUATION

APPENDIX E

EVALUATION REPORT ON VECTOR PROBLEMS RELATED TO THE BUREAU OF RECLAMATION'S PROPOSED COLUMBIA BASIN IRRIGATION PROJECT ADAMS, FRANKLIN, AND GRANT COUNTIES, WASHINGTON

U. S. Public Health Service, Communicable Disease Center
Technology Branch, Disease Ecology Section
Greeley, Colorado

and

Washington State Department of Health
Olympia, Washington

May 1964

APPENDIX E

EVALUATION REPORT ON VECTOR PROBLEMS RELATED TO THE BUREAU OF RECLAMATION'S PROPOSED COLUMBIA BASIN IRRIGATION PROJECT ADAMS, FRANKLIN, AND GRANT COUNTIES, WASHINGTON

INTRODUCTION

This evaluation report on vector problems is based on (a) information regarding the proposed project obtained from the report entitled "Water Resources Study, Columbia Basin Irrigation Project," prepared by the Water Supply & Pollution Control Program, Pacific N.W., Public Health Service, Portland, Oregon, April 1964; and (b) information on vector problems in the general area of the proposed project which has been obtained during the past decade by personnel of the Washington State Department of Health and the Communicable Disease Center, Public Health Service.

ANTICIPATED EFFECTS OF THE PROPOSED PROJECT ON VECTOR PROBLEMS

Studies conducted in Adams, Franklin, and Grant Counties have shown several species of mosquitoes of public health importance to be prevalent in the general area of the proposed irrigation project. These mosquitoes include *Culex tarsalis*, the common encephalitis vector, and several of the voracious *Aedes* species including *A. vexans*, *A. nigromaculis*, and *A. dorsalis*. The studies showed that mosquito-producing habitats in these counties are closely associated with irrigation agriculture and include water-filled depressions on pastures, irrigated fields and wastelands adjoining the irrigated areas, and ponds, seeps, marshes, and roadside ditches. The primary sources of water in the mosquito-producing habitats included seepage from irrigated lands, direct runoff from fields, seepage from canals and ditches and residual irrigation water. Based on the findings of these studies, it is presumed that mosquito problems in the area of the proposed project will be intensified as additional lands and water are devoted to irrigation agriculture unless appropriate preventive and control measures are planned and built into the project and continued as a part of the normal annual operational program. The relationships between irrigation agriculture and mosquito problems are discussed in Appendix A.

In addition to the foregoing general comments regarding effects of the proposed project on vector problems, the Washington State Department of Health comments more specifically on the anticipated effects as follows:

The East High Canal Project of the Columbia Basin Irrigation Project will add to an existing vector and disease problem caused by the developed parts of the Columbia Basin Project.

It will follow the pattern of the existing irrigated areas of the Columbia Basin Project unless preventative measures are planned into it. This pattern is characterized by (1) a sharp increase in the population density, both permanent residents and migratory workers; (2) an increase in populations of small towns in the project or even creation of new towns; (3) a marked increase in the number and size of the bodies of water, particularly in the summer time; and (4) a resultant change in the mosquito population from an Aedes population to a predominately Culex tarsalis population peaking in July and August, and a concomitant rise in the equine encephalomyelitis virus activity.

There are currently three authorized mosquito districts adjacent or encompassing portions of the proposed project. The Franklin County Mosquito Control District, is currently inactive; the Moses Lake Mosquito Control District, is becoming active; and the Adams County Mosquito Control District, is a full-time program with an annual budget in excess of $32,000. The Adams County Mosquito Control District's main control effort is expended in the irrigated areas of the Columbia Basin Project with some minor efforts in the areas of Lind, Cunningham, and Hatton. The proposed project may triple the total workload of the mosquito control district.

Prevention of the mosquito breeding is cheaper to the area over the life of the project. Good drainage in the coulees, particularly large ones, will prevent the formation of wet lands and the resultant mosquitoes. Drainages of pockets is essential. The project should provide such drainage to protect the health and well-being of the population and to minimize the long range cost to the property holder.

Since the water is available often before the revised tax base makes money available, the project should anticipate reimbursements to the mosquito control districts for mosquito control costs incurred before the tax base has been established.

RESPONSIBILITY FOR VECTOR CONTROL

Responsibility for vector prevention and control is normally associated with land ownership or operating rights. Therefore, the agency, group, or individuals responsible for various aspects of the proposed project should be prepared to accept full responsibility for the prevention and control of vector problems resulting from the design, construction, operation, or maintenance of the project. By making provisions for the prevention and control of man-made vector sources, the overall benefits of the project can be greatly increased.

RECOMMENDATIONS

In order to minimize public health hazards, every possible effort should be made to avoid creating conditions favorable for the production of mosquitoes and other arthropods of public health importance. It is therefore recommended that the principles and practices for prevention and elimination of mosquito sources associated with irrigation outlined in Appendix B be adhered to in the design, construction, operation, and maintenance of the project.

APPENDIX E-1

Relationships Between Irrigation and Mosquito Sources

The production of mosquitoes and other aquatic insects of public health importance occurs in many western irrigation areas, particularly where the water is applied by surface methods. Natural mosquito habitats are present in most irrigated areas, but usually man-made mosquito sources are far more important. These man-made aquatic habitats are frequently caused by the same faulty irrigation and drainage practices that result in serious soil and water problems such as excessive water losses, waterlogging, erosion, salt and alkali accumulations, damage to soil structure, leaching of plant nutrients, and reduced crop yields. Some of the "on-field" and "off-field" mosquito sources commonly associated with irrigation in the west are briefly discussed in the following sections.

On-Field Mosquito Sources

Prolific mosquito production occurs in low areas on fields used for pastures, hay meadows, and other close-growing forage crops where irrigation water often remains ponded long enough for the larvae to mature. Mosquitoes are sometimes produced on fields planted to irrigated row crops such as cotton, but usually ponded water is not present on these fields long enough for the aquatic stages to complete their development. Surface water must be present for at least 4 or 5 days in order for the aquatic stages to mature and produce adult mosquitoes. Rice is the only field crop that thrives when flooded this long. Observations in several areas have shown that when irrigation water is ponded on pastures and hay meadows long enough to produce mosquitoes, the desirable forage grasses and legumes are frequently killed and replaced by undesirable wetland plants. Thus, the extended flooding which is conducive to mosquito production is unfavorable for satisfactory growth of the common field crops.

In California, tremendous numbers of *Aedes nigromaculis* are produced in the ponded areas on irrigated pastures. Some of these pastures are irrigated 10 to 15 times from April through October and a brood of mosquitoes may be produced in the ponded water that remains after each irrigation. Investigations in the Milk River Valley of northern Montana showed that over two-thirds of all mosquito production (mostly *Aedes dorsalis* and *A. vexans*) on a 5,000-acre study area occurred in ponded areas on irrigated alfalfa fields, pastures, and western wheat grass meadows. In this valley, the irrigation water frequently remains ponded on the hay meadows long enough to produce *Culex tarsalis*, the encephalitis mosquito. Studies in Nebraska showed that large numbers of both *C. tarsalis* and *Aedes* mosquitoes are produced in ponded areas on irrigated pastures and hay meadows along the North Platte River. The use of irrigated mountain meadows for the production of hay and supplemental grazing of livestock is widespread in the Rocky Mountain

States. In many of the mountain valleys, the bottomland meadows are flooded almost continuously throughout the spring and early summer months. Ponding also occurs in numerous low areas following irrigation later in the season. The extensive aquatic habitats that occur on many irrigated mountain meadows produce tremendous numbers of encephalitis and other irrigation mosquitoes.

In addition to the depressions on irrigated fields, water sometimes remains ponded in the field laterals and drains long enough to produce encephalitis and other irrigation mosquitoes. This type of mosquito source occurs most often in areas having fine textured soils and poor underdrainage. Field laterals and drains that contain excessive amounts of vegetation are more favorable for mosquito production. Mosquitoes may also be produced in the residual water in various hydraulic structures, such as drops in ditches, particularly when they contain tumbleweeds and other debris. Mosquito production in hydraulic structures is usually of minor importance in comparison with that which occurs in other types of "on-field" aquatic habitats.

Rice fields constitute a special type of "on-field" mosquito source, since the flooding used for growing rice is very favorable for mosquito production. In rice fields of the Mississippi Delta and Gulf Coast areas, large numbers of *Psorophora confinnis* and *Psorophora discolor* are produced by intermittent irrigation; and *Anopheles quadrimaculatus*, the malaria mosquito, is produced in the constantly flooded rice fields. Rice fields in California are usually flooded throughout the growing season and they provide favorable aquatic habitats for production of *Culex tarsalis*, the encephalitis mosquito, and *Anopheles freeborni*, the western malaria mosquito. Large numbers of *A. nigromaculis* and *A. dorsalis* mosquitoes are frequently produced by the initial flooding of rice fields in California.

Off-Field Mosquito Sources

In many western irrigated areas, widespread and prolific mosquito production occurs in a variety of aquatic habitats located outside the boundaries of irrigated fields. These mosquito sources include roadside ditches, borrow pits, depressions on nonirrigable land, and numerous other undrained areas that are flooded by surface runoff from irrigated fields and other excess irrigation water. Such aquatic habitats often contain dense vegetation which makes them more favorable for mosquito production. The semipermanent and permanent water areas are highly favorable for *C. tarsalis*, the encephalitis mosquito. Those with fluctuating water levels produce large numbers of this mosquito as well as several vicious-biting *Aedes* species.

The types of "off-field" habitats just described accounted for more than one-fourth of the total mosquito production on a 5,000-acre study area in the Milk River Valley of northern Montana. In the North Platte Valley of western Nebraska, wasteland areas, roadside ditches, borrow pits and other undrained areas flooded by runoff from irrigated fields and overflow from conveyance systems were found to be important sources of both *C. tarsalis* and *Aedes* mosquitoes. Playas or land-locked depressions, flooded by runoff from irrigated fields, were responsible for three-fourths of all mosquito production on study areas in the Texas High Plains. These playas produced large numbers of *C. tarsalis* and several other species of irrigation mosquitoes. In certain western areas, large nonirrigable areas are wildly flooded with excess irrigation water for use by ducks and other waterfowl. Such areas are highly favorable for the production of tremendous numbers of *Aedes* mosquitoes. Several of the abatement districts in California and Utah spend large sums each year to control mosquitoes produced on waterfowl areas of this type.

Mosquito sources are often associated with the main irrigation conveyance systems, portions of which are sometimes located on nonirrigable lands. A large amount of irrigation water is often lost by seepage and leakage through the beds and banks of unlined canals and laterals which are located in pervious material. In areas having poor underdrainage, these seepage losses alone or in combination with deep percolation from irrigated fields often result in marshes and ponded water in roadside ditches, borrow pits, and other areas. In many western irrigated areas, aquatic habitats created by seepage produce large numbers of mosquitoes. Permanent and semipermanent seepage areas have been found to be especially favorable for the production of *C. tarsalis*, a vector of encephalitis. Large numbers of *Aedes* mosquitoes are also produced in seepage areas that have fluctuating water levels.

Mosquito production may also occur in various other "off-field" aquatic habitats associated with the main irrigation conveyance systems. These mosquito sources include flooded areas resulting from overflow of poorly maintained canals and laterals; ponded areas where conveyance channels block natural drainageways; residual water in turnouts, stilling basins, and other hydraulic structures; surface pools created by leakage from water control structures; and residual water in conveyance channels during nonoperational periods. Although these types of aquatic habitat contribute to the total mosquito problem, they are generally of less importance than those caused by seepage and the numerous other "off-field" mosquito sources.

APPENDIX E-2

Principles and Practices for Prevention and Elimination of Mosquito Sources Associated with Irrigation

A. Project Conveyance and Distribution Systems

1. Lining or other satisfactory seepage control measures should be provided for all sections of canals and laterals located in porous material where excessive leakage would result in waterlogged areas, seeps, and ponds.

2. Drains should be installed to prevent ponding of excess irrigation water and natural runoff along the upper side of canals and laterals. All drainage crossing or inlet structures should be placed on grade to avoid ponding.

3. Borrow areas should be self-draining to keep them from retaining ponded water.

4. Where possible, provision should be made to prevent turnouts and other hydraulic structures from retaining residual water when they are not being used.

5. Effective measures should be provided to prevent ponding of leakage from water control strucutres.

6. Every effort should be made to establish delivery schedules which will provide farmers with adequate but not excessive amounts of water at proper intervals to insure efficient irrigation of the crops concerned.

7. Vegetation and debris which would retard normal flows should be periodically removed from conveyance channels, water control structures, and drains.

B. Project Drainage Systems

1. Trunk drainage systems should be installed to insure complete removal and proper disposal of excess irrigation water, natural runoff, and seepage from both irrigable and nonirrigable lands affected by the distribution and use of irrigation water on the project.

2. Drainage ditches should be designed, constructed, and maintained so as to minimize ponding in the channels and to insure free flows at all times.

3. Provision should be made to prevent water from ponding behind spoil banks.

4. Underdrains, culverts, inlets, etc., should be placed on grade to prevent ponding.

C. Irrigated Farms

1. The sponsoring agency and other organizations concerned with irrigation agriculture or mosquito control should do everything possible to encourage irrigation farmers to use the following irrigation and drainage practices which will prevent or minimize mosquito sources:

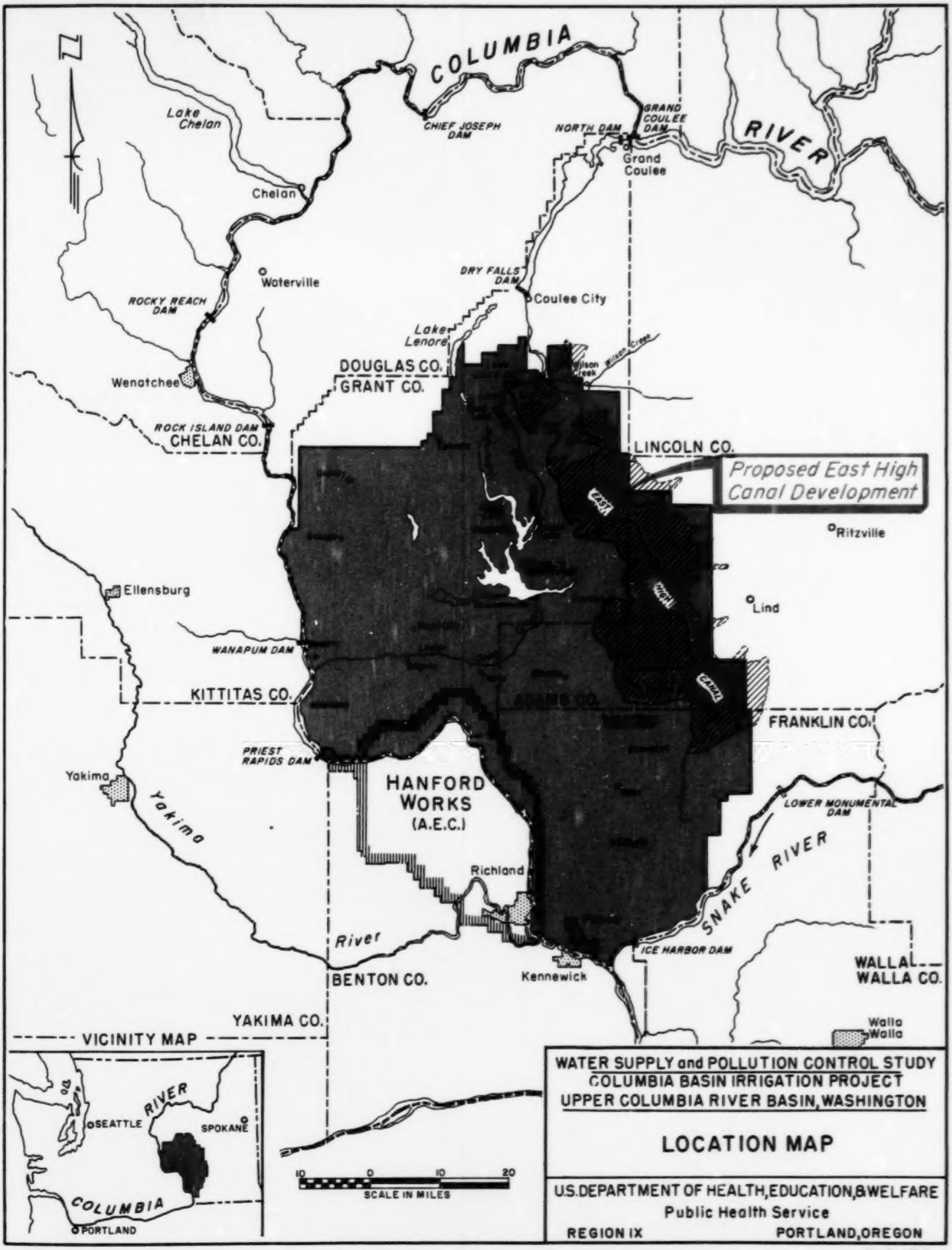
    a. The farm supply system, drainage system, and field layouts should be properly fitted to the topography, soil, water supply, crops to be grown, and irrigation methods to be used.

    b. All surface irrigated fields should be properly leveled or graded to provide for efficient water application and removal of excess water without ponding.

    c. An adequate drainage system should be provided for removal of excess water from all portions of the farm.

    d. Irrigation methods should be used which will provide optimum irrigation efficiencies.

    e. Application of irrigation water should be limited to that required to fill the crop root zone plus unavoidable losses and excess water needed to prevent upward movement of salts.


COLUMBIA
RIVER
Lake Chelan
CHIEF JOSEPH DAM
NORTH DAM
GRAND COULEE DAM
Grand Coulee
Chelan
Waterville
DRY FALLS DAM
Coulee City
ROCKY REACH DAM
Lake Lenore
Wilson Creek
Wilson Creek
DOUGLAS CO.
GRANT CO.
Wenatchee
ROCK ISLAND DAM
CHELAN CO.
LINCOLN CO.
Proposed East High Canal Development
EAST HIGH CANAL
Ritzville
Ellensburg
Lind
WANAPUM DAM
KITTITAS CO.
ADAMS CO.
FRANKLIN CO.
PRIEST RAPIDS DAM
HANFORD WORKS (A.E.C.)
Yakima
Yakima
LOWER MONUMENTAL DAM
SNAKE RIVER
Richland
River
ICE HARBOR DAM
Kennewick
BENTON CO.
WALLA WALLA CO.
YAKIMA CO.
Walla Walla
VICINITY MAP
RIVER
SEATTLE
SPOKANE
COLUMBIA
PORTLAND
10 0 10 20
SCALE IN MILES

WATER SUPPLY and POLLUTION CONTROL STUDY
COLUMBIA BASIN IRRIGATION PROJECT
UPPER COLUMBIA RIVER BASIN, WASHINGTON

LOCATION MAP

U.S. DEPARTMENT OF HEALTH, EDUCATION, & WELFARE
Public Health Service
REGION IX PORTLAND, OREGON

FIGURE I